SOUVENIR OF THE STREET RAILWAY CONVENTION
HELD IN CLEVELAND, OHIO, OCTOBER 19, 1892

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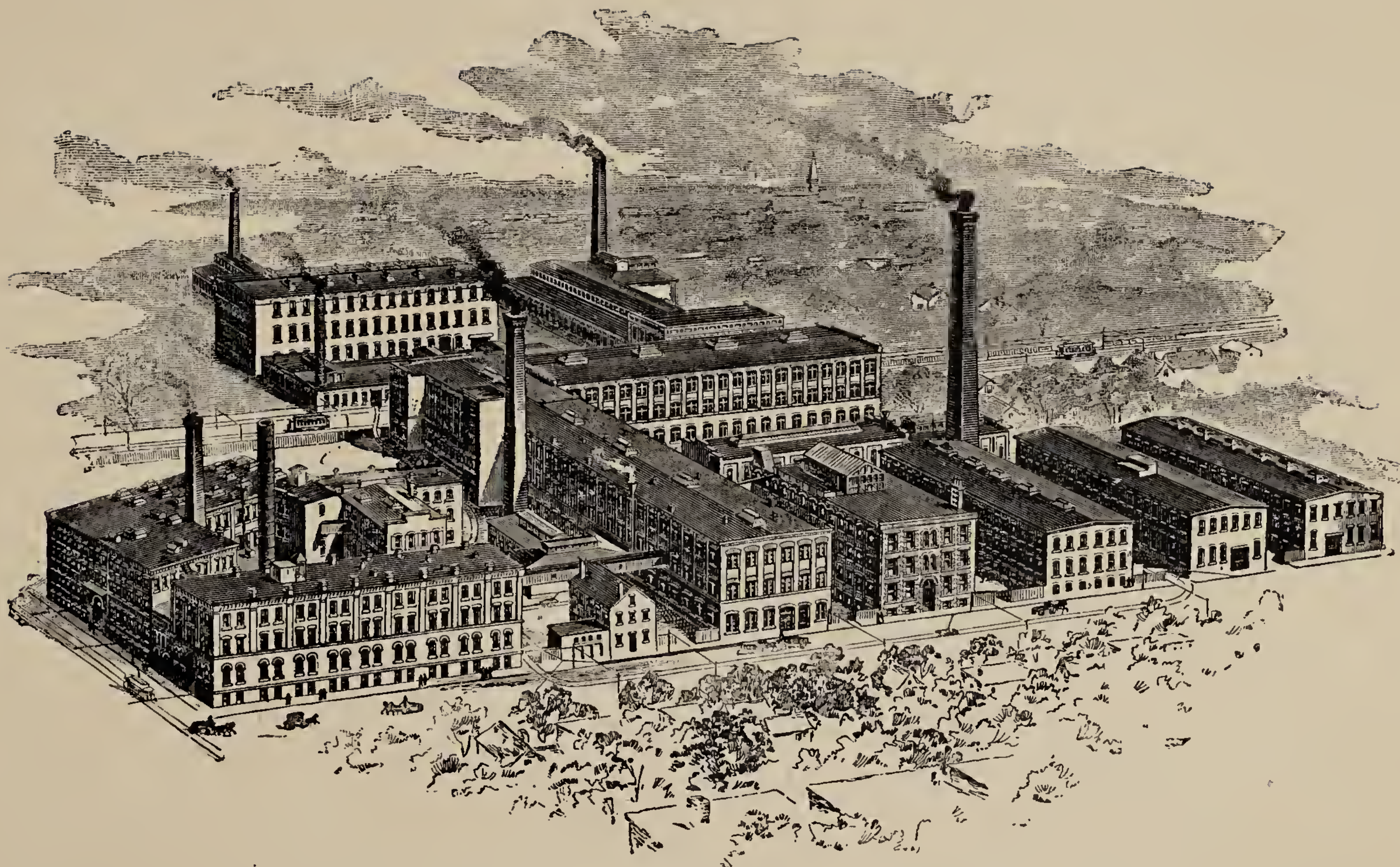
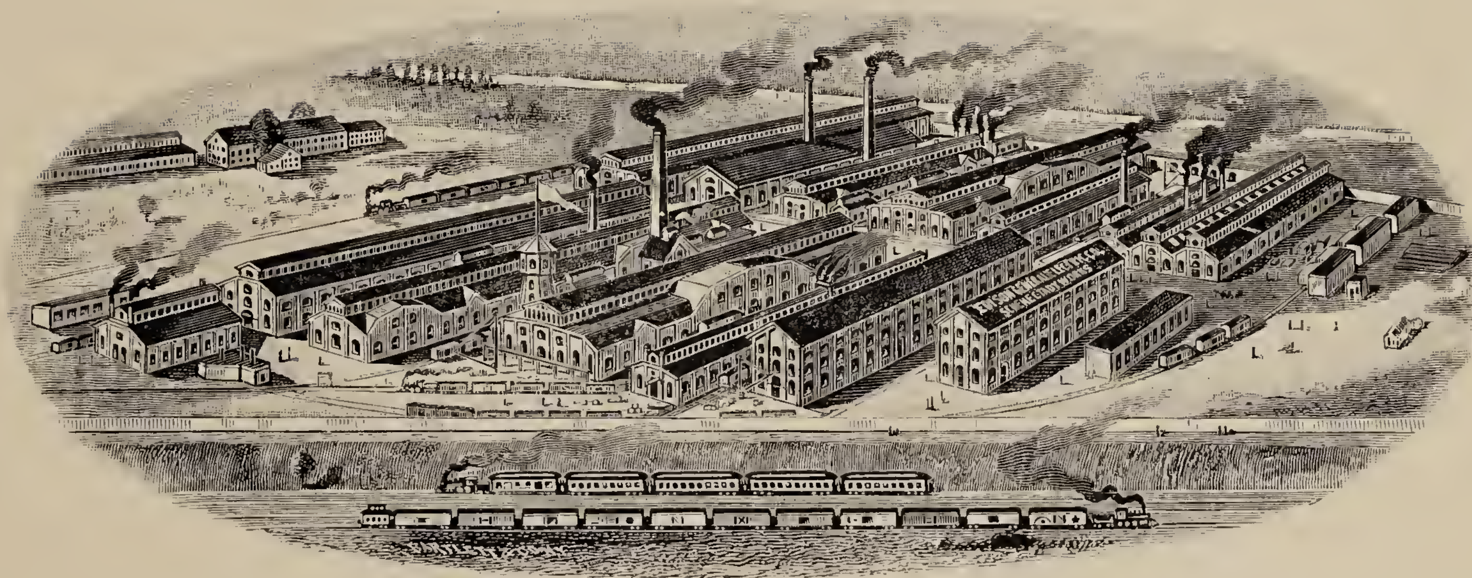
THIS PAGE SHOULD FOLLOW PAGE 102.

Data on the Construction and Equipment of Electric Railways, Wire Tables, Etc.

THE T.-H. ELECTRIC COMPANY'S FACTORY IN 1882, NEW BRITAIN, CONN.



THE GENERAL ELECTRIC COMPANY'S FACTORIES, LYNN, MASS.



THE GENERAL ELECTRIC COMPANY'S FACTORIES, SCHENECTADY, N. Y.

Railway Power Generators.

The multipolar railway power generators, manufactured by the General Electric Company, may be divided into two main types: namely, direct-coupled and belt-driven generators. Both types of generators are manufactured in four different sizes, as follows: —

DIRECT-COUPLED GENERATORS.	BELT-DRIVEN GENERATORS.
M. P. 12 — 1500 — 75	M. P. 4 — 500 — 350
M. P. 10 — 500 — 90	M. P. 4 — 300 — 400
M. P. 6 — 250 — 90	M. P. 4 — 200 — 425
M. P. 6 — 250 — 195	M. P. 4 — 100 — 650

The classification of these generators consists of the letters M. P., standing for the word "multipolar," followed by three numbers separated by dashes, indicating respectively the number of pole pieces on the machine, the kilowatt output, and the speed of the armature in revolutions per minute.

Direct-coupled Generators.

The M. P. 12–1500–75 is a generator of 2,000 horse-power capacity, and weighs approximately 165,000 pounds. As its title indicates, it has twelve pole pieces, a maximum output of 1,500 kilowatts, and an armature speed of 75 revolutions per minute. It is wound for a potential of 500 to 600 volts, and is overcompounded to compensate for a 10% drop. Its commercial efficiency is 96%, which means that with 2,000 horse-power delivered to the crank-shaft by the engine 1,920 horse-power will be delivered at the terminals of the machine in the form of electrical energy.

The frame of this immense generator is a circular casting of solid steel 15½ feet in diameter. The armature is 10½ feet in diameter with three-foot width of face. The commutator is constructed on a separate solid frame of circular form, which is firmly bolted to one end of the armature core. It is 7 feet in diameter, 20-inch width of face, and has many novel features in its construction.

The General Electric Company has orders for nine of these immense generators, which are the largest direct-current machines ever constructed, and the first of these will be completed about the end of this year.

The M. P. 10–500–90 is constructed for an armature speed of 90 revolutions per minute, so that it can be coupled direct to an ordinary Corliss engine. Its capacity is about 675 horse-power. The frame of the machine is 12 feet in diameter, and resembles in many respects the frame of the 2,000 horse-power generator just described. The armature is 8 feet in diameter,

with a 2-foot width of face. This generator forms a convenient unit for railway service where the 2,000 horse-power machine would be too large.

The M. P. 6–250–90 is the smallest direct-coupled generator manufactured by the General Electric Company, which is designed to be driven by an ordinary Corliss engine. It is of about 315 horse-power capacity. Another machine of the same capacity as this is intended to be coupled to a high-speed engine making from 195 to 200 revolutions per minute. It is, of course, a much lighter machine than the M. P. 6–250–90, and makes a very convenient as well as an economical unit for railway service. It more closely approximates the English practice in direct-coupled machines than the others.

Belt-driven Generators.

The M. P. 4–500–350 is the largest belt-driven generator built. Its capacity is about 675 horse-power. The machine has been run under a load of 1,200 amperes without injury, and will stand even more than this for short periods. It will run from no load to full load without any sparking or necessary shifting of the brushes. It may be belted direct to slow-speed engines without the use of countershafting. It has a commercial efficiency of 95%, and shows a very small increase in temperature even after a twenty-four hours run under full load. Many of these machines have been made for the West End Railway Company of Boston and the Brooklyn City Railway of Brooklyn, New York, and great satisfaction has been expressed in both cases by the engineers in charge for the efficient manner in which these machines operate.

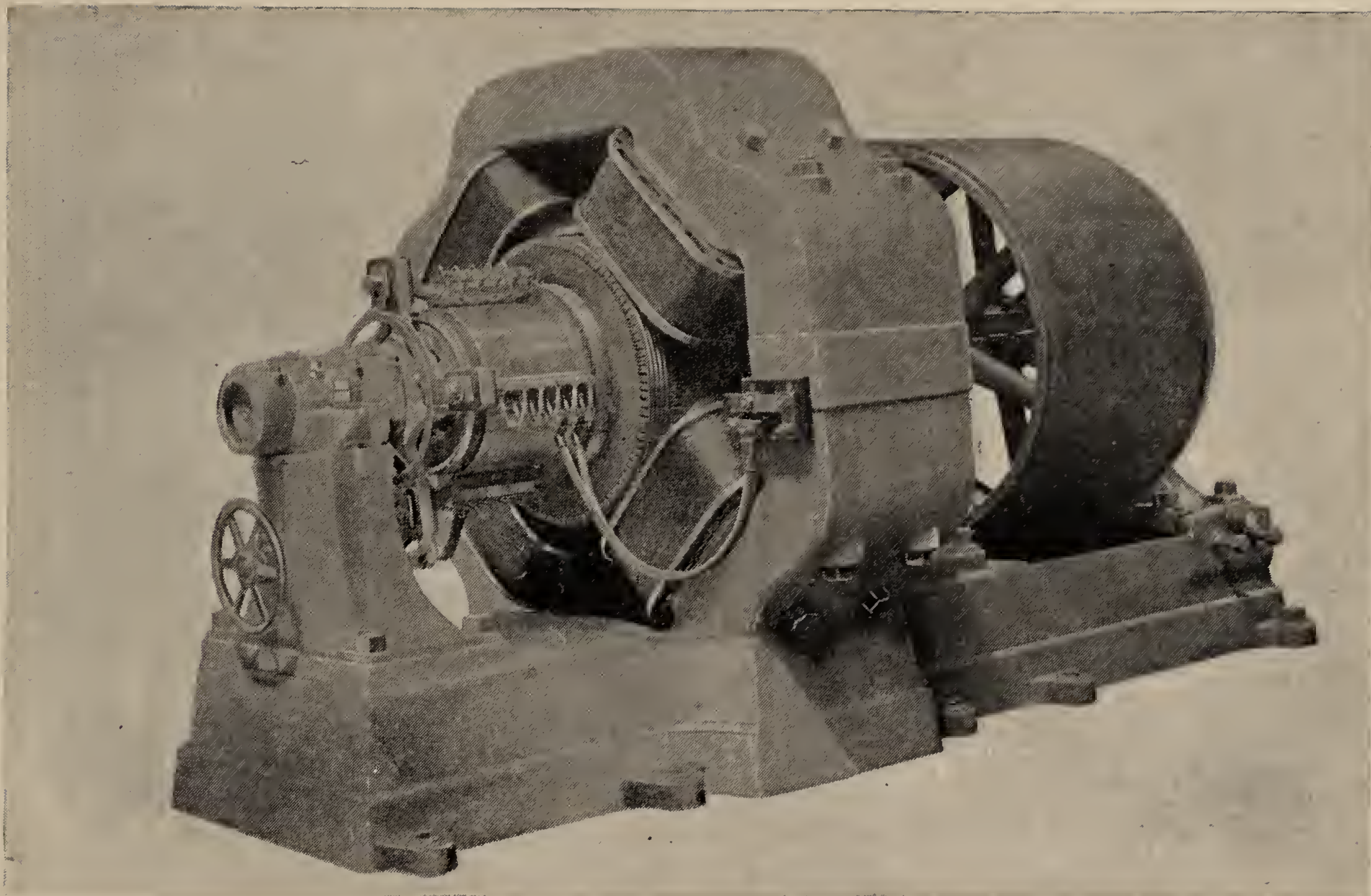
The M. P. 4–300–400 is of exactly the same type as the 675 horse-power machine just described. Its capacity is about 400 horse-power. An illustration of the M. P. 4–300–400 is

shown on the opposite page, and a capital idea of the general appearance of all the belt-driven generators may be obtained from it. The M. P. 4–300–400, as well as the smaller machines of this type, is mounted on a foundation capped with heavy rails so that it may be moved backward or forward in a direction at right angles to the armature shaft so as to take up the slack or loosen the tension, of the driving belt as may be necessary. It may also be mounted on a fixed foundation, as is the M. P. 4–500–350, and provided with an ordinary belt-tightener. This latter method is strongly recommended where the distance between the centres of the dynamo and engine-shafts is short.

The M. P. 4–200–425 is of the same type as the two preceding machines, and has as good a record in satisfactory performances.

The preferred way of operating these machines is to couple two of them to a short jack-shaft carrying a pulley belted directly to the engine. Two heavy friction clutch couplings are used between generators and the jack-shaft so that one or both machines can be run as desired. In this way the engine will be of such size as to give a good economy, and yet the generating unit will be sufficiently small to be quite conveniently handled, with the additional advantage that an accident to either generator only incapacitates half of the unit.

The M. P. 4–100–650 is a generator of about 133 horse-power capacity and is the smallest multipolar dynamo for railway work manufactured by the General Electric Company. It resembles the three larger sizes of belt-driven generators except that it has no third bearing for the armature shaft outside of the pulley. It is a very popular size of machine and is now in operation on electric railways in all parts of the country.



M. P. 4-300-400 RAILWAY POWER GENERATOR.

The four different sizes of both these types of generators are now standard products of the General Electric Company's factories. They embody all the features essential to a successful railway power generator. They have an ample cross-section of iron in the frame, the armature is of very low speed as compared with generators previously manufactured, they keep a low temperature even after long runs under full load, and the insulation of all parts is so perfect and repairs are so easily effected, that the expense of maintenance of a large railway power-plant consisting of these units of power is an extremely small item.

The most striking feature of both the direct-coupled and the belt-driven types of these generators is the armature. It is built upon the same principle in both machines, and is of what is known as the ironclad ring type. The iron core is built up (laminated, as it is called) of pieces of sheet iron, and is mounted upon two heavy spiders solidly keyed to the forged steel shaft. The characteristic difference between the Gramme ring and the ironclad ring armature is that, while in the former the winding is upon the surface of the iron core, in the latter the surface is slotted so that all the copper in the winding is inside of the outer circumference of the iron lamination. By this method the space or air-gap between the armature and the inside faces of the pole pieces may be made smaller than is safe or even possible with the surface winding of the Gramme ring armature. Decreasing this space, decreases the resistance of the magnetic circuit, which means an increase in the efficiency of the machine.

A novel and valuable feature in the construction of the armature is the method used to dispense with binding wires. The slots in which the copper conductors are placed are of dovetail shape, so that the width of the slot on the surface of the core is very much smaller than its diameter

inside. A solid wooden wedge is driven in over the copper conductor and its insulation and under the projecting edges of the iron, and thus, notwithstanding the centrifugal force generated by the armature when running, holds the winding firmly and solidly in place. This method has the further advantage that repairs to a damaged conductor or its insulator, may be very quickly and easily made, by simply driving out the wooden wedge and unfastening the connections at the ends of the copper bars or conductors. The copper bar and its insulation can then be removed and new ones substituted.

The low temperature kept by these armatures, after long runs under heavy load, is obtained by a peculiar method of ventilating the iron core. The core, as it is built up, is provided with numerous radial apertures from the inner to the outer surface of the armature, and the fan action of the spider arms of the armature draws the air in along the shaft to the interior space of the armature core and forces it out through these ventilating slots.

Great attention is given to the quality of the material used in the construction of all these railway generators, and all material is subjected to a rigid test before being accepted.

The electrical efficiency of these generators is from 97 to 98%, and the commercial efficiency from 94 to 95%, according to their size. The electrical efficiency of a generator is of but little interest to the user, but is mentioned here to prevent a misunderstanding often caused, from the fact that the electrical efficiency is often mentioned as being the commercial efficiency of the machine.

These large multipolar generators will play a most imporant part in all railway work in the future, and it is believed that there will be but little change except in detail for some time to come.

The S. R. G. Railway Motor.

After an extensive experience, covering a period of over two years, in manufacturing a double reduction railway car motor, the General Electric Company made a departure from the designs previously followed, and as a result of several months of experimenting produced a single reduction, slow-speed machine known as the S. R. G. Railway Motor. This machine is practically ironclad, as it has two interior pole pieces, and the magnetic circuit is completed, both through the nosepiece at the front end and through the frame yoke at the back.

The field spools, which are designed with a view to the greatest economy of space, practically surround the armature, on the same principle as the field winding of the well-known Thomson–Houston arc dynamo.

The armature of the S. R. G. Motor is of the Gramme Ring type, and possesses many important advantages over the drum, or Siemens armature, previously used in railway work. It has a greater raditating surface, and, therefore, accumulates very much less heat under heavy loads than a solid drum armature, and, as an even great advantage, it can be very easily repaired; an injured coil may be removed and replaced without disturbing the rest of the winding. This is a point which all electric railway men will appreciate.

The iron core of the S. R. G. motor armature is built up of thin sheets of iron, "laminated," as it is called, in order to prevent, as far as possible, all magnetic losses, and the high commer-

cial efficiency shown by these motors, is an excellent proof of the great care which is taken in their design and construction.

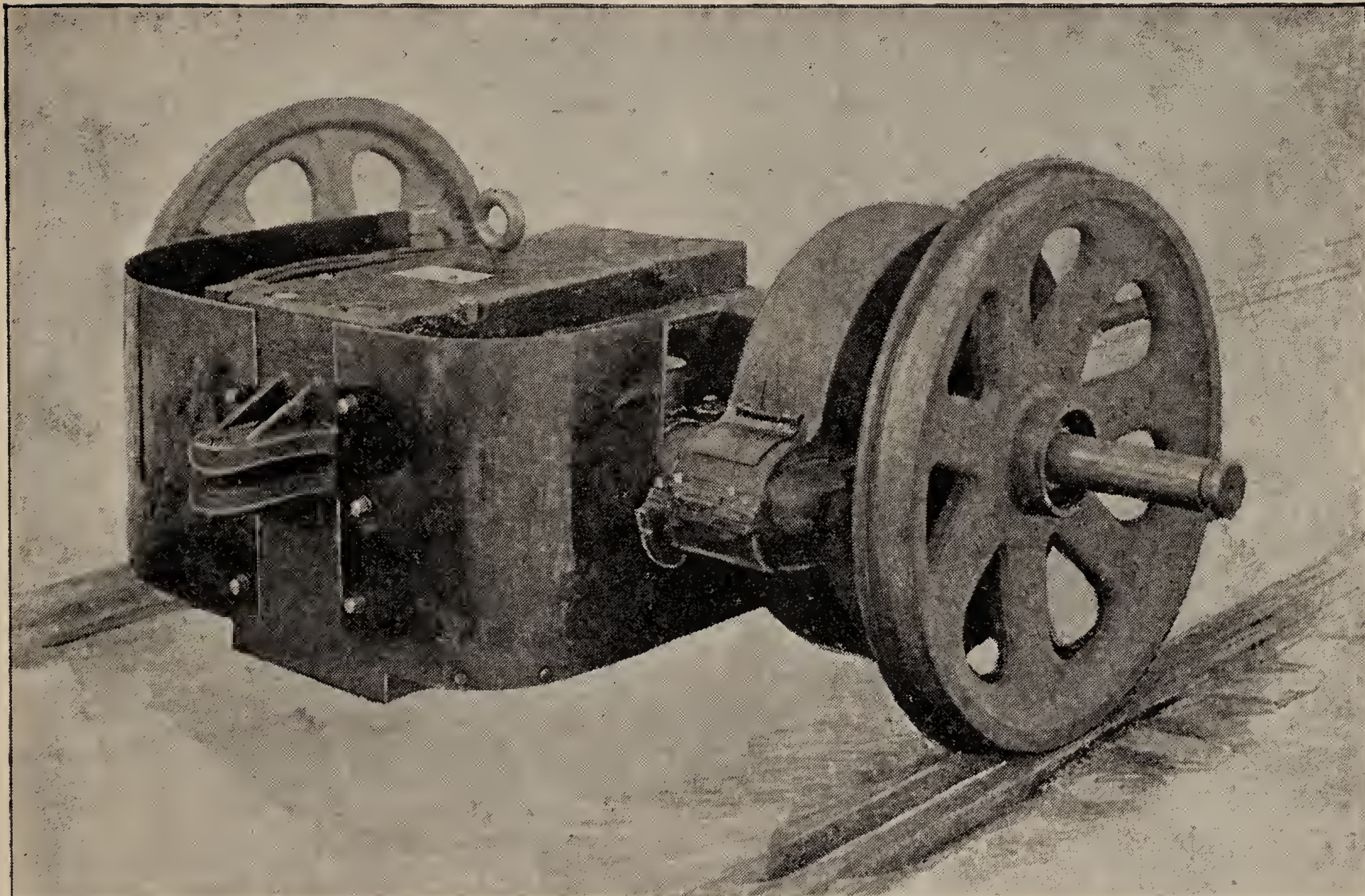
The commutator used on the armature of the S. R. G. motor is very similar to that previously used on the double reduction motor, and does not differ from it in any very material respect. It is made of the purest copper and is well insulated throughout with the best quality of mica.

The brushes used are rectangular blocks of hard carbon, copper-coated, with the exception of the surface which bears upon the commutator, so that good contact will be made between brush and holder.

The brush yoke is set in a horizontal position and needs no change, in any respect, when the motor is reversed. The brushes are of easy access for inspection or removal.

The armature pinions and the axle gears, with which the S. R. G. motors are equipped, are of steel, with ample width of face to withstand the heaviest strains. They are enclosed in metal cases, which are perfectly oil-tight and dust-proof. A moderate amount of heavy grease is placed in the case, so that gear and pinion are always thoroughly lubricated. The gear case is made in two parts, divided horizontally, and in the upper part is a small opening fitted with an oil-tight lid, by means of which the gears may be inspected, without the trouble incident to removing the gear case itself. Practical experience with gears enclosed and lubricated in this manner proves that the wear of the teeth is very much less than is the case with exposed gears, and that the cost of maintenance of gearing, which otherwise would be a large item, is reduced to a minimum.

The S. R. G. motor is supported on its truck at two points. At the axle end, it is placed in a



THE S. R. G. RAILWAY MOTOR.

rigid position, so that there will be no mechanical loss in the gearing, and, at the front end of the frame it is supported by the nose-plate, which plays between rubber cushions, bolted to the arch bars of the truck. This allows some little spring to the motor and lessens the rigidity of its action in starting, making it easier for both armature and gears.

The W. P. Railway Motor.

All practical electric street railway men know that an efficient motor and one which has the most perfect self-protection from all injury, is the best motor for street railway service. The General Electric Company has always appreciated the necessity of perfecting a railway motor of this kind, which should have the greatest possible degree of self-protection against mechanical injury from any source, and its position as the largest manufacturing company of electrical railway apparatus in the world, has enabled it to do this thoroughly and well.

The single-reduction waterproof motor (W. P. Motor, as it is called) embodies all the important features essential to a successful motor. It is a motor that can be used for the equipment of narrow as well as standard gauge roads. It is of comparatively light weight, and consists of a minimum number of parts. It has a frame of such strength and construction, that breakage is an impossibility, and the protection of the interior parts is absolutely perfect. These points in the construction of the W. P. Motor, as will be seen at once, place it far in advance of any other motor now in use.

In order that the excellent design and workmanship of these motors may be fully appreciated, they are described in detail as follows: —

The Motor.

In general appearance the motor is small and compact and an observer is at once struck with its simple design and the fact of the small number of parts, which enter into its construction.

The length of the armature shaft is such that the motor may be used to equip roads of three-foot gauge, while its dimension from the nose-plate to the centre of the axle-bearings is so small, that two may be mounted on a truck with only a five-foot wheel base.

The Motor Frame.

The frame consists of two shell-shaped, steel castings clamped together by bolts at the front and back, the axle brasses being held between the two parts. The armature bearings are cast in one piece with the lower half of the frame, and are provided with caps so that the linings may be inspected or renewed without disturbing other parts of the machine. The lower half is shaped somewhat like a bowl, rounding up from a plow-shaped bottom which will throw aside stones or other obstructions that may be upon the track. The parts of the frame are hinged together at the axle end, and by simply removing four bolts the upper half may be raised through a trap in the car floor, or the lower half swung downward into a pit under the track, whichever may be most convenient. The field coil or armature can then be easily removed. The motor can be run through, or stand in water, up to the lower side of the armature bearings without damage, and water may freely drip on the top without danger of entering it. All the metal in the frame of the motor forms a part of the magnetic circuit, so that there is no deadweight whatever in its construction.

The Gearing.

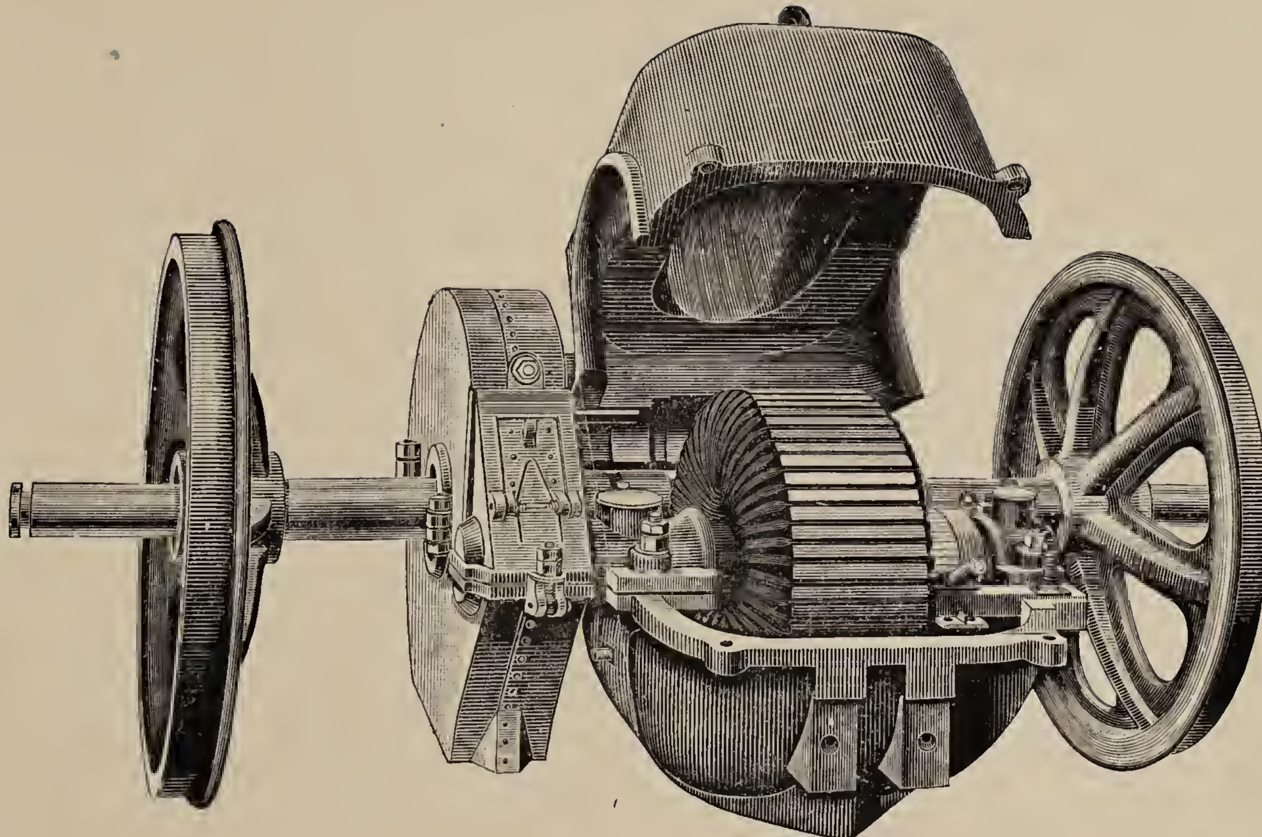
The armature pinion and axle gear are of steel, of ample width of face to stand the heaviest strains of railway service, and are run in an oil-tight case filled with grease, to ensure free and

continuous lubrication and to exclude all dust and grit. The gear case is made in two parts and has a small opening in the top half, fitted with an oil-tight lid, through which the gears may be inspected or oil introduced.

Practical experience with gears of this material, so enclosed and lubricated, proves that there is very much less wear, than was the case with the old unprotected gears, subjected as they were to the grinding action of the dust inevitably raised by a rapidly moving car, and that the cost of maintenance of gearing, which before was a large item, now becomes a very small one.

The Armature and Field.

The armature shaft is made short and heavy, to avoid the possibility of springing, and is fitted with steel shells on its bearings, so that in case of wear from long use, or injury from grit, they may be easily and quickly replaced and a proper bearing always ensured. The linings of the boxes are of punched sheet metal, just thick enough to stand the wear required of them, and when thrown away and replaced by new ones, but little metal is wasted. The armature, as well as the motor, is entirely ironclad. The armature core is a ring, with projecting teeth of a peculiar form, solidly fastened to the shaft. The coils are wound between the teeth and firmly held in place by wooden wedges. No binding wire is used, and to replace an injured coil it is only necessary to drive out the wedge, when the coil can be rewound without disturbing any of the others. The armature winding is such that there is no crossing of wires, and, as it is below the surface of the iron core, it is perfectly protected from any mechanical injury arising either from a foreign substance getting between the armature and pole pieces, or from the rubbing of the



THE W. P. 30 RAILWAY MOTOR.

armature against a pole piece, on account of wear of the bearings. The one field coil of the motor is placed above the armature and exerts upon it a solenoidal pull, so proportioned, that, at normal load, the armature bearings are largely relieved of its weight. This is a remarkable feature of the machine and will serve to greatly diminish the wear of the bearings. The ironclad armature permits the use of much less clearance between the armature and the pole pieces, than was safe where the armature was wound on the surface, and the smaller air gap materially decreases the magnetic resistance of the circuit. This means less weight, less heating of the field spool, and a greater efficiency of the motor.

Other Advantages.

The brush-holders are mounted in slots, planed in the edge of the lower half of the frame, on each side of the armature bearing. By simply taking out a bolt, the brush-holder may be taken entirely from the motor, to examine or renew a brush. The convenience of such an arrangement is apparent. It obviates the necessity of reaching down into the motor to adjust a holder or to replace a brush, possibly too hot to be comfortably handled.

These motors, before shipment, receive a most thorough electrical and mechanical test at the works of the Company. In regular service, on over a hundred and fifty roads throughout this country they have proved to be highly efficient and able to withstand the roughest usage without injury.

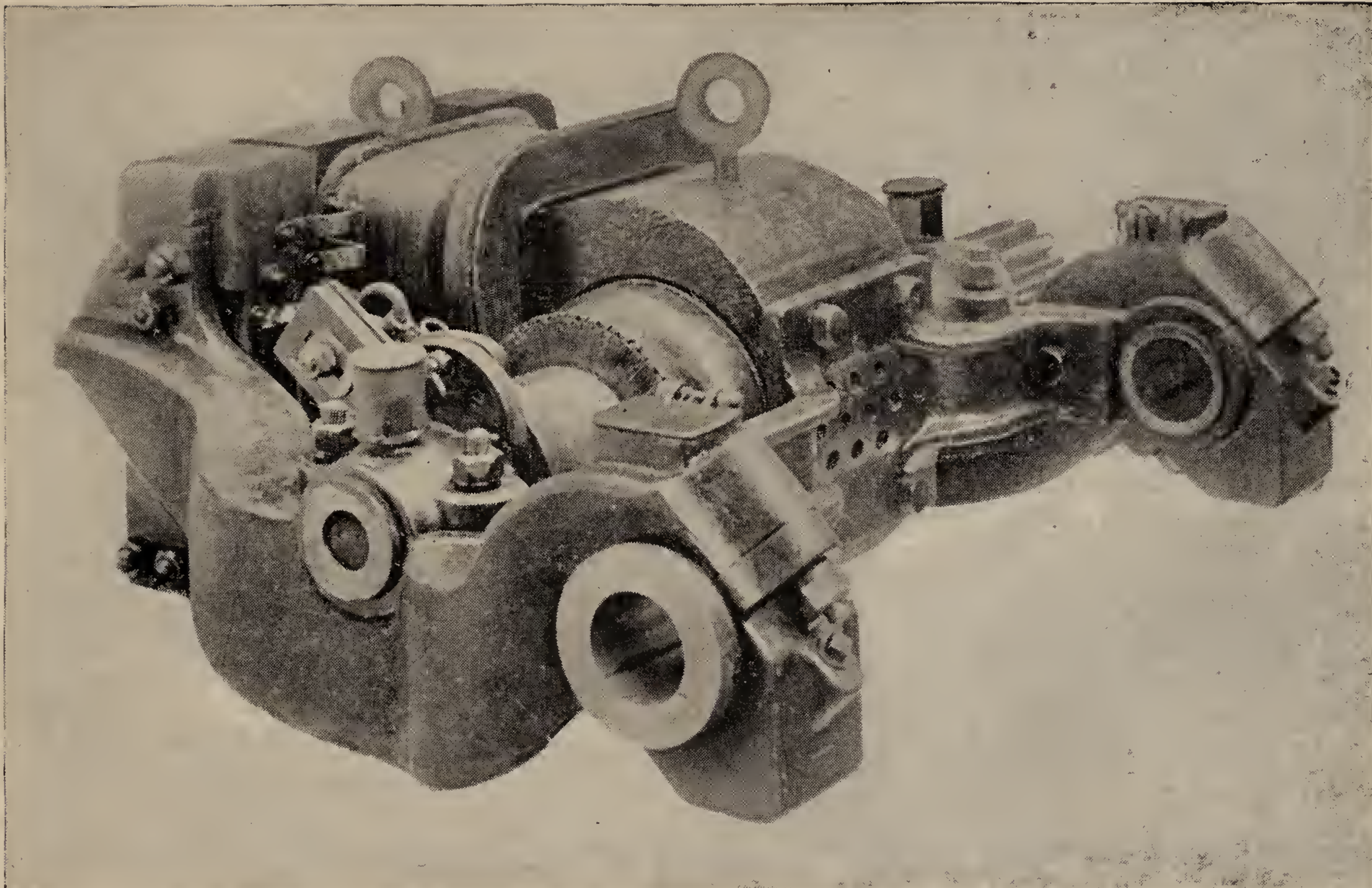
The S. R. F-30 Railway Motor.

The many advantages of the single reduction motor for electric railway service have, during the past year, been so emphatically proven, that the General Electric Company has re-designed its old double reduction F-30 motor as a single reduction machine, giving it the new name of the S. R. F-30 railway motor, and, in compliance with the demand, already apparent, for the conversion of F-30 motors, the company is now re-building, for many of its customers, quite a number of these machines.

The manner in which the F-30 has been changed to the S. R. F-30 is as follows: The side-arms, nose-plate, intermediate shaft, pinion and gear of the old motor were discarded and replaced by new side-arms, designed to support the motor proper (as will be seen in the illustration) in a position exactly the reverse of the position of the old F-30, by a new nose-plate, which is really no longer a nose-plate, but merely a support to the ends of the pole pieces, and by a pinion and gear exactly the same as those used on the General Electric Company's W. P. railway motor.

The method by which the armature speed has been reduced one half, and the torque of the motor increased to approximately twice its strength, has been by merely doubling the number of turns or convolutions in the winding of the armature, the fields spools remaining unchanged.

The armature bearings of the new motor are the same as those of the old type, though better arranged for lubrication, and the axle bearings are now similar to those of the armature, so that the same kind of grease should be used on both armature and axle shafts.



THE S. R. F-30 RAILWAY MOTOR.

In comparing the S. R. F with the F motor, it has been found that the efficiency of the new type is several per cent. higher than that of the old, though its speed under the same conditions of strength of field, etc., is slightly less. The torque, or horizontal pulling effect, is higher than in the F-30, although after a run under full load, the new motor did not show as great a rise in temperature as its predecessor.

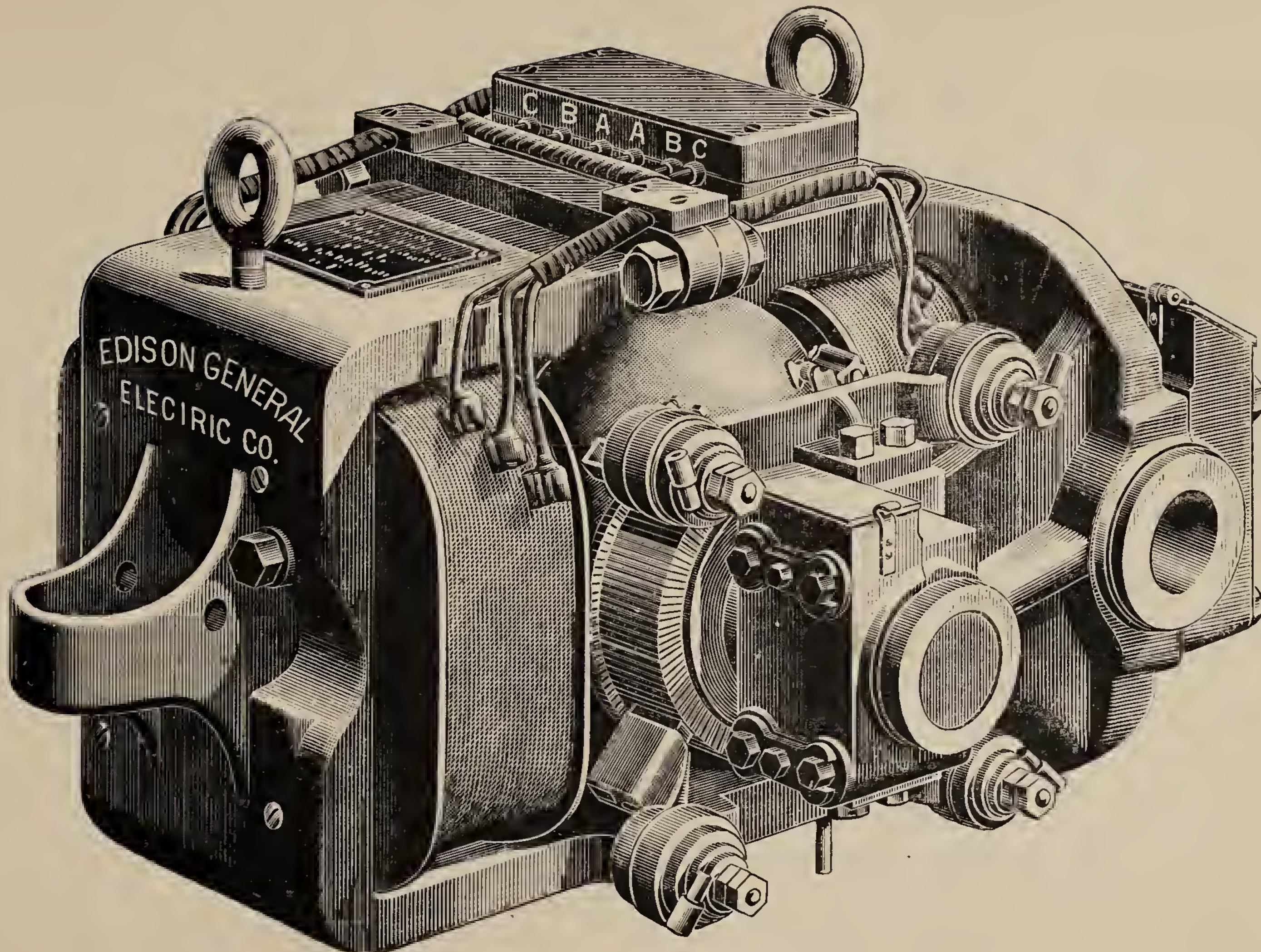
The results of the experiments and trial tests made with the S. R. F motor speak well for its usefulness in the future, and it is believed that this unique idea of turning around the old F-30 motor and changing it to a single reduction machine, will be perfectly satisfactory wherever followed.

The Edison No. 16 Railway Motor.

The Edison number 16 railway motor is a single reduction machine of the multipolar ironclad type, and includes all the latest improvements of railway practice. The frame is of soft steel, cast in two parts and firmly fastened together by heavy steel bolts.

The armature of the motor is of the Gramme Ring type with a commutator of the latest design, made without the outside collar, so that the brushes have a perfectly clear surface on which to run, out to the end of the commutator segments. German silver wire is used for the connections between the commutator and the armature coils. The core of the armature is built up, or laminated of soft sheet-iron rings after the usual method, and is supported upon the shaft by two heavy aluminium bronze spiders, bound together laterally by long steel bolts.

The gearing of the motor consists of an armature pinion and a split axle gear with very carefully machine-cut teeth, and with an ample width of face to carry the heaviest strains of service.



EDISON No. 16 RAILWAY MOTOR.

The Power-station Switchboard.

A Railway Power Switchboard, composed of units or panels, each of which comprises within itself all the apparatus essential to the operation of one generator, is of interest not only as regards the original equipment of a station, but also as an important feature, considering the ease with which additions can be made, when it is intended to enlarge an existing plant. A description of panels designed with reference to the above may perhaps best serve to bring out the particular advantages.

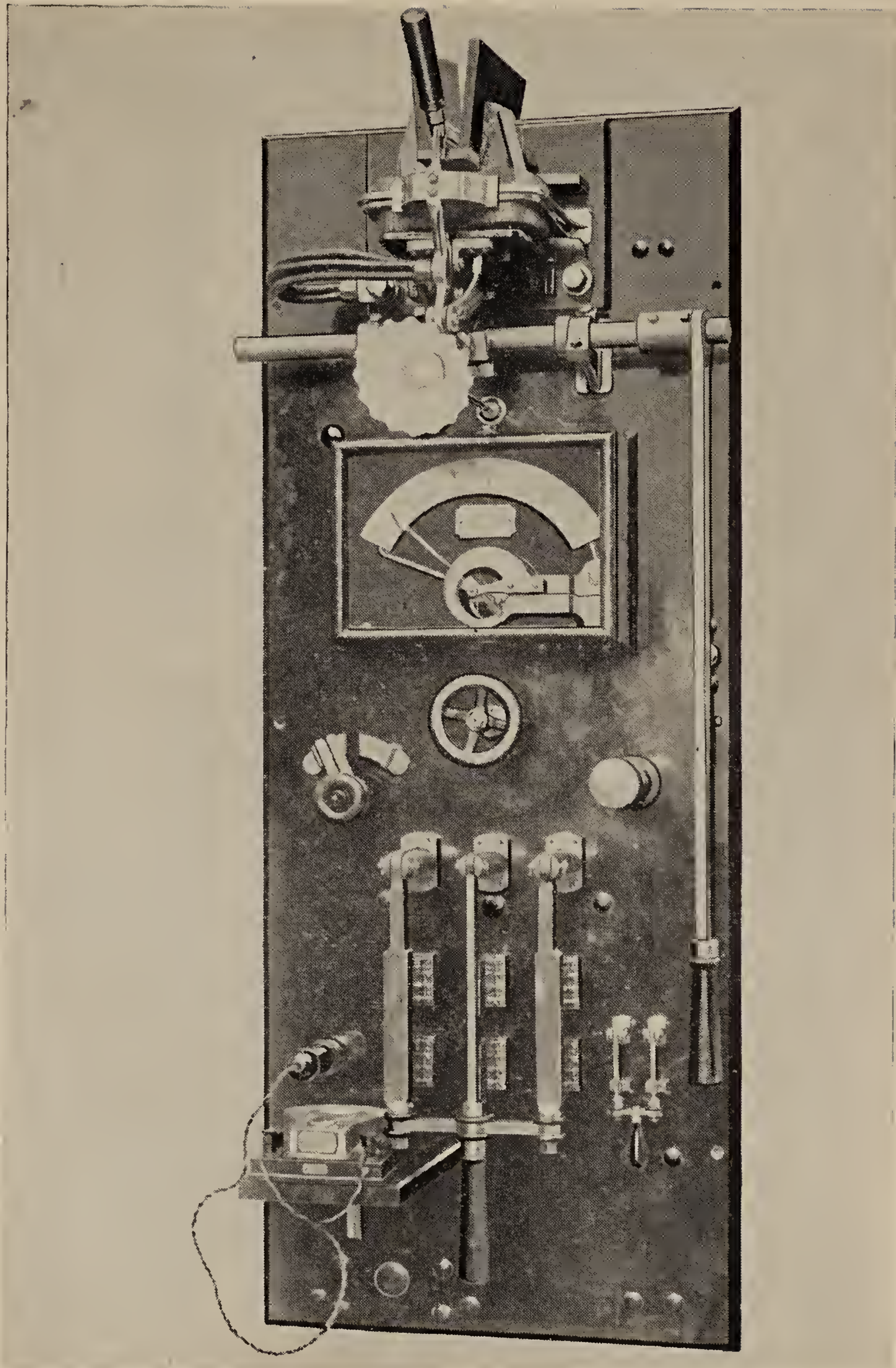
That portion of the panel on which the instruments are placed, is manufactured for four capacities: 200, 400, 600, and 1,000 amperes; the location of the instruments, bus bars, etc., being similar in each case. The dimension of this panel is the same for each class, being 62 inches high by 24 inches wide. It is thus possible to make up a uniform switchboard comprising any or all of the different classes, or to interchange one with the other without any alteration.

The panels may be of slate, marble, or any other insulating material. The panel is secured to vertical angle irons, leaving a space of 28 inches between the lower edge of the panel and the floor. In this space is set a plain base panel which may be of any material preferred. The panels, for the different generators, are secured to each other by means of bolts which run through the projection of the angle iron on the back of the board, and the switchboard as a whole is secured by braces extending from these angle irons to the wall.

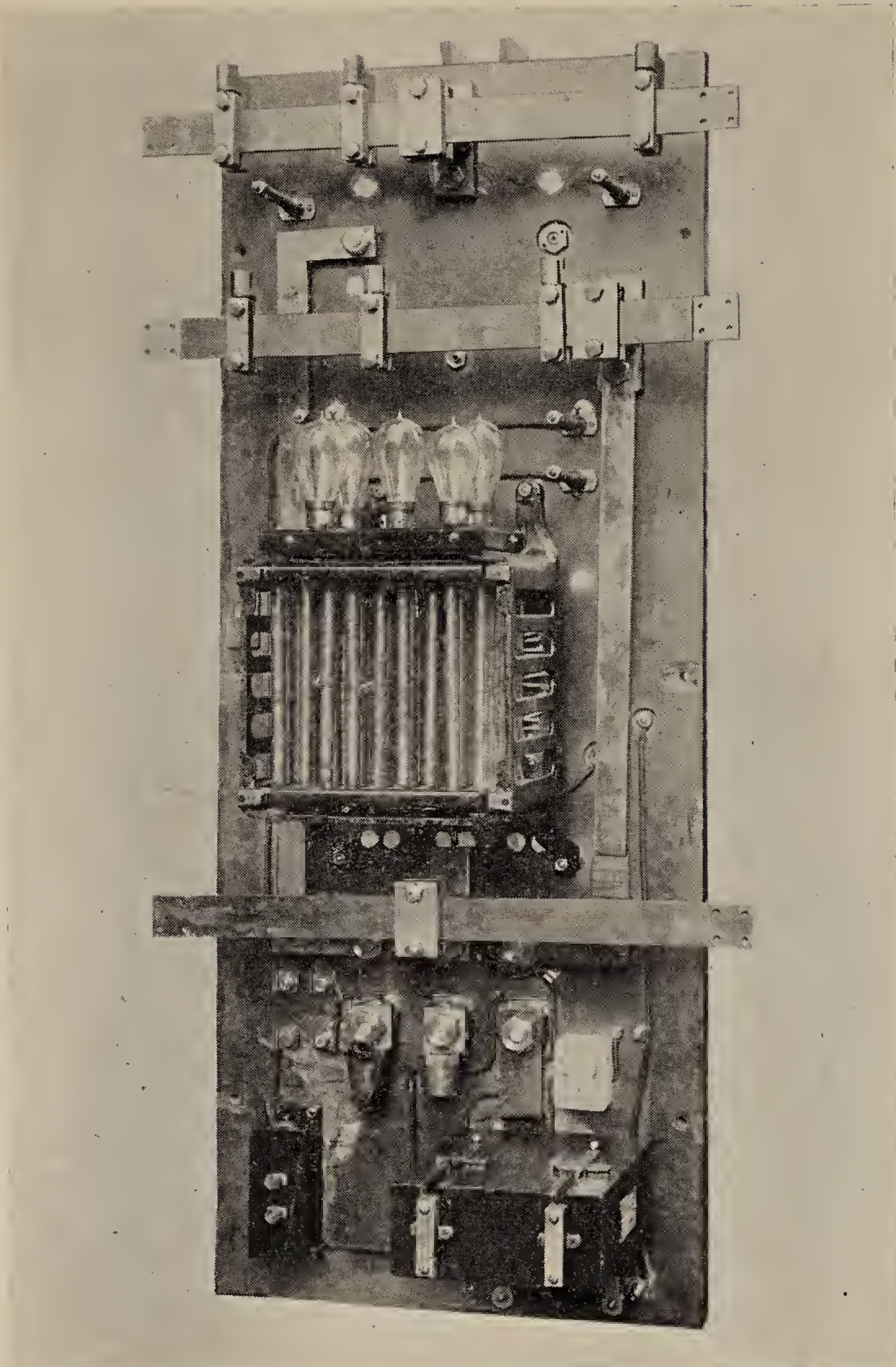
On the front of the panel at the top is placed the automatic circuit-breaker, an instrument

for automatically opening the circuit in case of excessive overload or short circuit on the line. Where there are several panels in the switchboard, the automatic circuit-breakers are fitted with a resetting device so that all may be closed at once, to guard against excessive load being thrown on one of the generators. Beneath the circuit-breaker is placed the regular Thomson–Houston current indicator. This is lighted by a bracket lamp extending from the switchboard. Below the indicator is the hand-wheel of the rheostat, the spindle of which extends through the panel. To the right of this hand-wheel, projecting from the panel, is a flash-lamp, connected in series with the five lamps on the rheostat, which answers as an indicator when building up the generator. To the left of the hand-wheel is the field circuit switch of the generator. Below the hand-wheel is the triple-pole main switch. To the right of this is a small double-pole switch which connects the bus wires for the lighting circuit, with the generator leads, between the generator and the main switch, thus making it possible to operate the lights when the main switch is open, and also preventing their being extinguished when the circuit-breakers are open. To the left of the main switch is the potential receptacle and the shelf which supports the voltmeter.

On the back of the panel, at the top, is placed the ground, or negative, bus bar connected through its supports to the terminal of the circuit-breaker. Next below this is the positive bus bar, connected through its supports to the terminal of the current indicator. Clamps are furnished for attaching the line and ground feeders to their respective bus bars. Below the positive bus bar are the two bus wires of the lighting circuits. Underneath these is the rheostat. The equalizer bar is immediately below the rheostat and is connected, through its supports, to the centre terminal



PANEL SWITCHBOARD. FRONT.



PANEL SWITCHBOARD. BACK.

of the main switch. The magnetic cut-out for the voltmeter circuit and the main circuit lightning arrester are in the lower right-hand corner, and the magnetic cut-out for the lighting circuit is in the lower left-hand corner. The connections on the panel are complete, and when installing the switchboard the only electrical connections required are the three main leads and the two field wires from the generator and the necessary ground and line feeder wires.

The Series Parallel Controller.

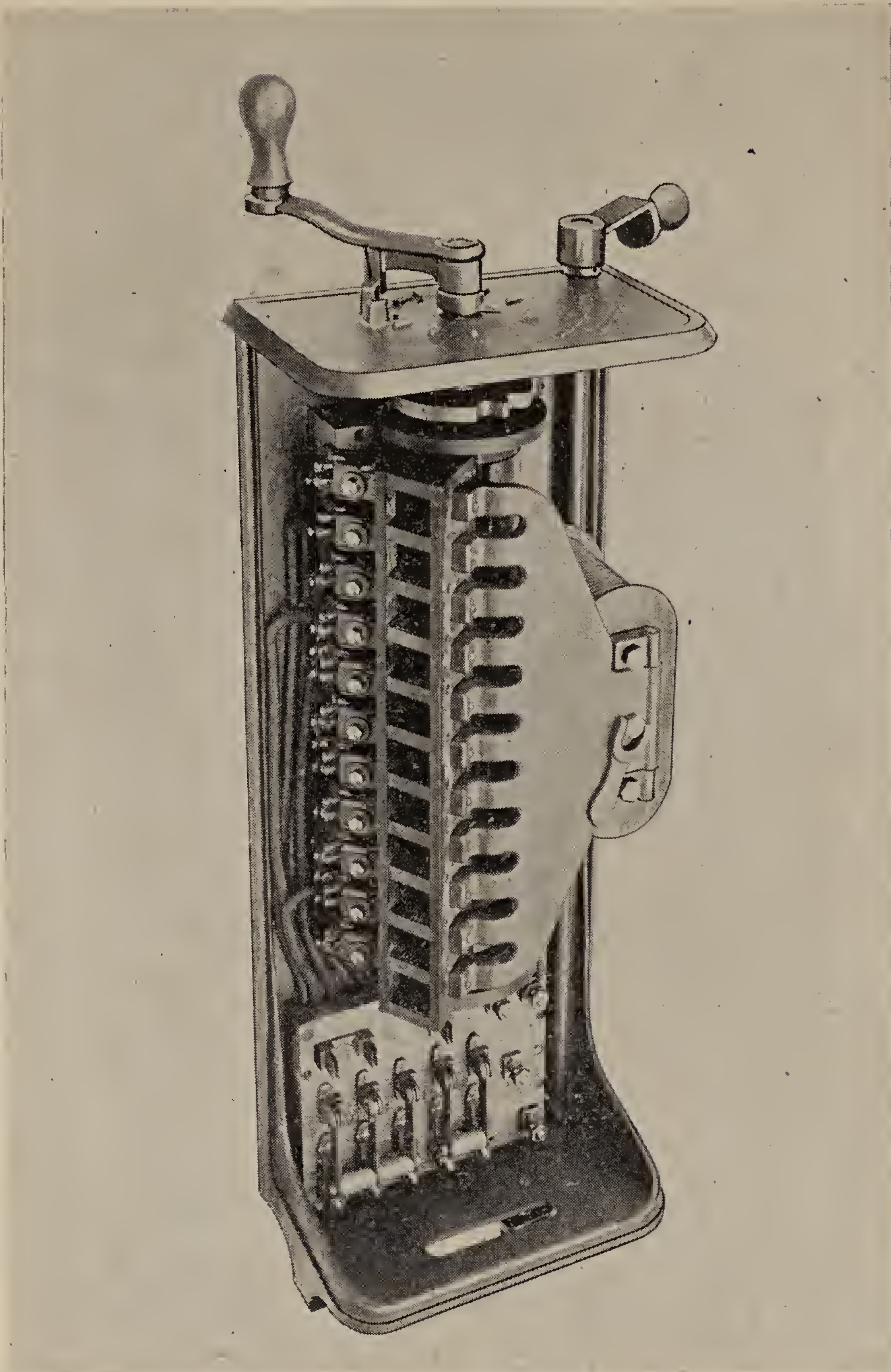
The increasing demand for greater speed and power in electric car equipment and the necessity, where motors are designed for maximum speeds of forty miles an hour, of economically controlling the same at low speeds, as in crowded streets of cities, has led to the development of a Series Parallel Controller, fully qualified to handle the heaviest motors in city or suburban service.

The General Electric Company manufactures two forms of Series Parallel Controllers, known as Form D and Form E.

The former is an improved form of the type "J" Controller and has accomplished a most useful purpose where the work was suited to its capacity.

The Form E was developed to meet the demand for a Series Parallel Controller, for motors of the largest capacity and highest speeds, and also to overcome the objection raised by some against placing the controller underneath the car. To render the controller easily accessible, the new form, known as Form E, has been designed for use on the platform; although, if desired, it may be placed underneath the car, as that will in no wise affect its operation.

The connections of the different combinations are made by means of multiple metal contacts, pressing on rings, secured to the surface of a cylinder, these rings being separated from each other by annular grooves, from each of which projects a division piece slightly clearing the sides and bottom of the groove. These division pieces are secured to side-pieces which form as a whole a series of pockets in which the arcs are confined, preventing short circuiting between



SERIES PARALLEL CONTROLLER. FORM E.

adjacent contacts. All arcs, formed in the operation of the controller, are within the influence of a magnetic field, and are so arranged that the flashes are diverted from the ends of the contact rings and fingers to the sides of the same, at right angles to the circumference of the cylinder, thus protecting the contact surface from the arc. The energy of the arc and consequent heating is much reduced by opening the circuit at different points simultaneously. For instance: in the final break the circuit is opened at four places, with a corresponding reduction of destructive effect. The contact fingers may be readily removed for examination and the ends of the rings on the cylinder, where exposed to the arc, are fitted with tips that can be easily renewed.

The cylinder, through which the different combinations are made, is operated by a handle, fitted with a pointer which enables the motorman to determine at a glance the position in which he is running. As a further precaution, and to ensure the stopping of the cylinder at the proper points, a detent engages a disc notched to correspond with the running points. In practice these points are readily determined by sense of feeling, so that it is not necessary to watch the index.

The reversing switch spindle extends through the controller case, and is fitted with a crank which operates the reversing switches in the usual way.

In the lower portion of the controller is a connection-board to which the leads from the motors are attached. On this connection-board is an absolute cut-out switch enabling the motorman to entirely disconnect, from the circuit, either motor in case it should be disabled.

The Form E Controller has been subjected to a series of severe special trials, has been in regular service for some time, and has proved itself equal to any emergency.

The Combined Snow-sweeper Manufactured by the General Electric Company.

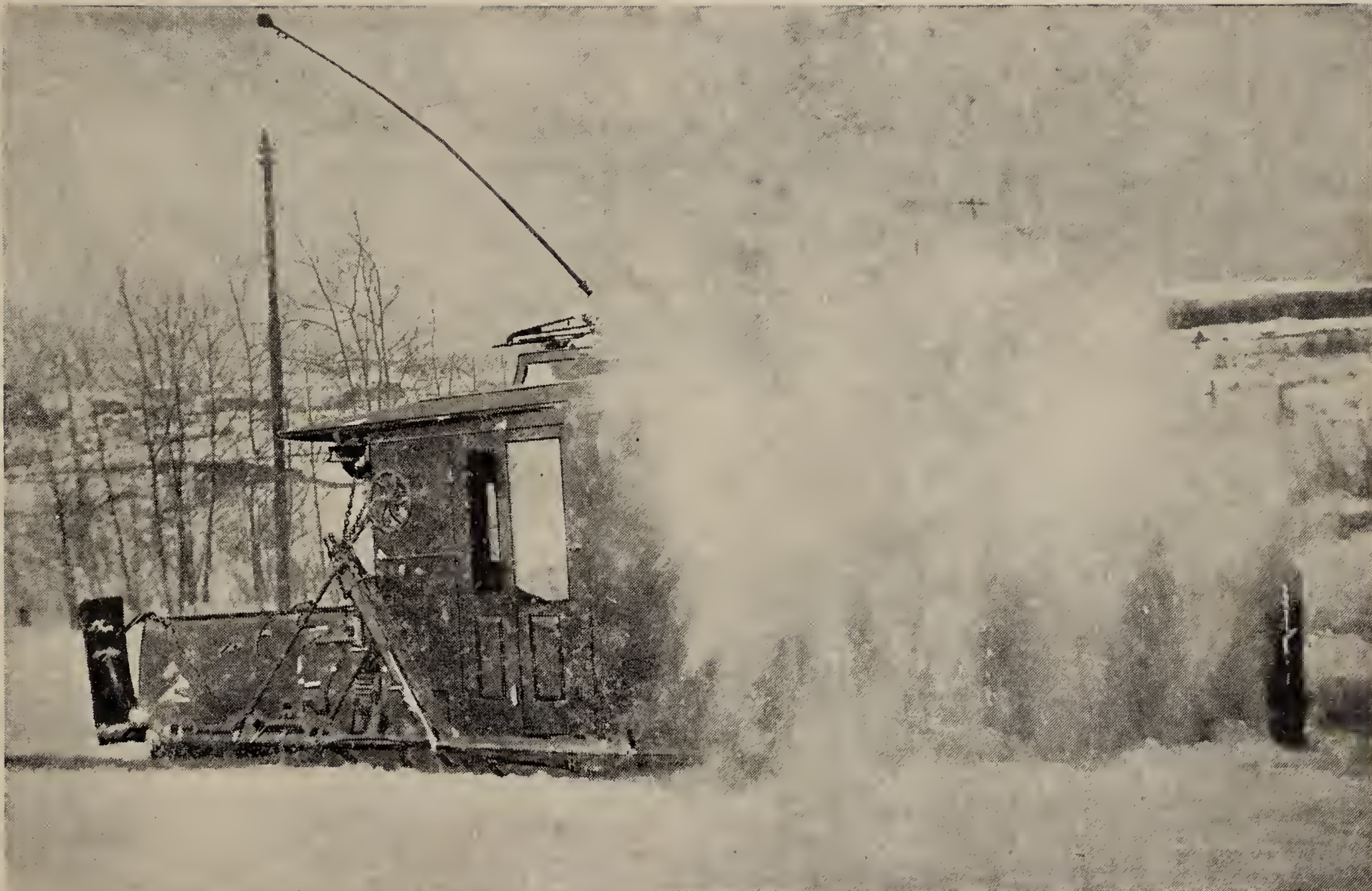
As the winter approaches, with its attendant trouble and delay in travel incident to heavy falls of snow, the attention of street railway men naturally turns to some adequate means of keeping their tracks cleared and car service regular. Realizing the importance of this work, the Railway Department of the General Electric Company has again given its attention to the subject of snow-sweepers.

The success attained by the snow-sweepers manufactured by this Company and put in operation last year, has convinced the engineers in charge of the work that the machine needed but few changes before being placed upon the market for the coming winter. The only important improvements which have been incorporated in the present machines are as follows: —

The steel brushes of the flyers have been given a projection of between 4 and 5 inches beyond the steel plates instead of two inches as formerly. An adjustable snow-deflecter has been added to the hood of the flyer to keep the snow, when brushed from the track, from being thrown too much in the air. Other than this the machine is practically what it was last year when it gave such good accounts of itself.

We publish herewith three illustrations of the combined snow-sweeper made from actual photographs taken in our northwest territory.

A WINTER DIFFICULTY.



THE SNOW-SWEEPER AT WORK.

A WELL-CLEANED TRACK.

The first is a graphic illustration of what street railways often have to contend with, and one of the chief sources of delayed travel — a heavy fall of snow. The accumulated drift, shown in the foreground, was cleared away by the combined snow-sweeper.

The second illustration gives a very good idea of the sweeper itself while at work, and the third is an excellent view of the track after the sweeper had passed over it, leaving a clean rail and roadbed.

The many testimonials in praise of the results of last season's work point to an even greater success of the sweeper during the coming winter. A detailed description of the machine including data and prices will be found in Bulletin of Information, Railway Department, No. 1001.

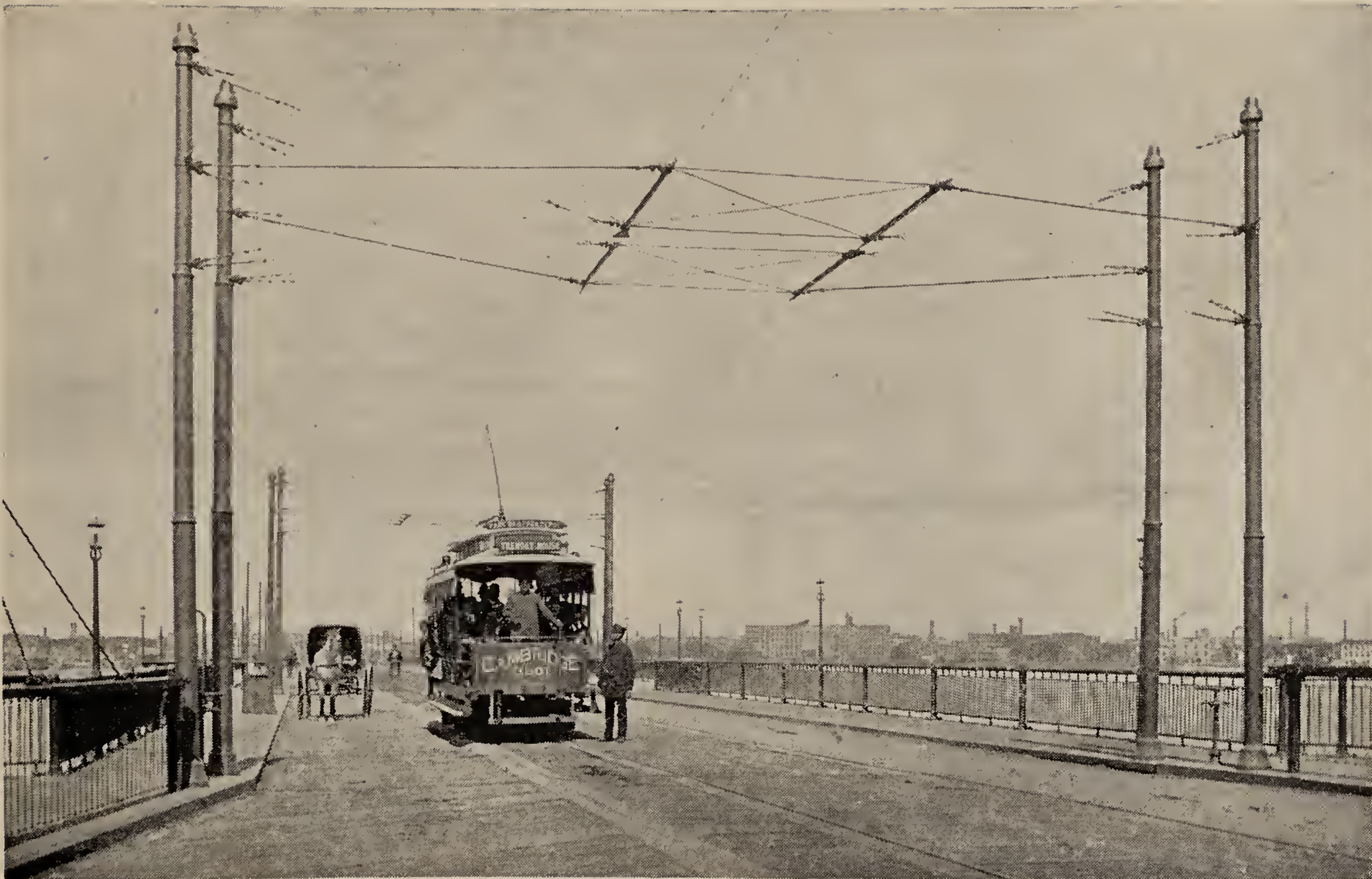
Overhead Line Construction, on the Harvard Bridge, Boston, Mass.

Although the new Harvard Bridge over the Charles River in Boston, has been finished and in use for nearly a year, and though the electric car rails have been laid for the same length of time, litigation has prevented, until within the last two months, the electrical equipment of the track. However, when this matter was adjusted, work was begun by the Street Railway Company and pushed to a speedy completion.

The accompanying illustrations taken from photographs of the bridge show the general appearance of the overhead line. The construction has been carried out according to the most approved methods of the present time and the line material used is of the latest and best types now manufactured. Great care has been taken, not only with regard to the durability of the line, but to its general appearance as well, and, as will be seen in the first illustration, the evenly spaced and well-set poles and neatly strung trolley and span wires form, as a whole, quite an ornamental addition to the bridge.

The second illustration shows a point of especial interest to electric railway men in connection with wiring bridges over navigable streams, namely, the method of construction, and the material used to obtain a practically continuous trolley wire over a drawbridge. In the present case the construction on the drawbridge is strong and at the same time neat in appearance and quite un-

HARVARD BRIDGE, BOSTON, MASS.



OVERHEAD DRAWBRIDGE CONSTRUCTION.

obtrusive, while the apparatus used is of light weight and thoroughly efficient in its work. Its action is briefly as follows: —

As will be seen in the illustration, the apparatus is put up so that the trolley wheel runs across from the end of the pointed terminal on to the flat pan-shaped end of the opposite one; the pointed terminal is suspended so that the end of the point comes under, though several inches below, the flat end of the other. As the trolley wire runs under the pointed terminal, it presses it up until the flanges of the trolley wheel come in contact with the second terminal. In this manner a mechanical connection is made and the trolley wheel runs on a practically continuous line.

The great advantage of this method of construction, especially where the drawbridge is frequently opened, becomes at once apparent, as the trolley wire is ready for use the instant the draw is closed. The West End Street Railway Company of Boston is to be highly complimented on the excellent manner in which this work has been done, and it is to be hoped that work of equal excellence is being put up throughout the country.

Coal Consumption on Electric Street Railways.

A point of interest to many railroad men, in connection with the operation of electric street railways, is the relation between the amount and cost of fuel used per horse-power hour at the power-station and the amount of power used per car-mile on the road.

The car-mile unit of course varies widely under different conditions; in fact, a fair comparison of two roads can never be made on this basis, except the roads are running under the same conditions of track repairs, size of cars, etc.; but assuming a general average, it will be seen that the ordinary conditions of operation are a 16-ft. double-motor box car, weighing, when filled to its full seating capacity, about 6 tons; a trackbed in moderately good repair, with grades seldom over 4%, and a power-station equipped with slow-speed engines, driving the dynamos by means of countershafting.

From the figures received from six electric street railways in different parts of the States of New York, Pennsylvania, and Massachusetts, using the General Electric Company's system, it is found that the average amount of coal used per horse-power hour at the power-station is about 5 lbs., while the average amount used per car-mile on the road, computed from a mileage of over 1,200,000 miles, is about 8 lbs., or over 50% more than the first quantity. It is also found from the figures of these roads, that the average cost of coal, as laid down at the power-station, is $3 per ton. From this it is seen that the cost of fuel per horse-power hour at the station and per car-mile on the road is respectively .75 cents and 1.20 cents. The figures from one road,

however, show that, under conditions very nearly allied to the general conditions assumed above, it is possible, by good management, to operate cars at a cost per car-mile no greater than the cost per horse-power hour at the station, so far as the item of fuel is concerned. This is a state of affairs which all electric street railway companies should strive to bring about, and little things, such as greased rails on sharp curves and well-kept switches and crossings, will go a long way to produce the desired effect.

Road.	State.	Time Covered.	Mileage.	Coal.		
				Cost per Ton.	Tons used.	Lbs. used per Car-mile
1	New York	3 months	754,359	$2.75	1,797.0	4.75
2	Massachusetts	2 ,,	34,162	4.50	206.7	12.10
3	Massachusetts	3 ,,	52,680	4.50	301.0	11.40
4	Pennsylvania	3 ,,	67,755	1.90	405.0	12.10
5	New York	5 ,,	296,924	2.60	928.0	6.30
6	Pennsylvania	1 ,,	63,028	2.10	116.6	3.70
	Totals		1,268,908		3,754.3	
	Averages			$3.06		8.40

Where and How to Locate the Power-station of an Electric Railway.

(From Crosby & Bell's Electric Railways.)

One of the first questions that arises in the construction of an electric railway is, naturally, the position and character of the power-station. It is not at all a simple matter, for there enter into it considerations of a rather complicated nature, all having a direct bearing on the economy of the future system. It is needless to say that the line should first be roughly located, in order to arrive at an intelligent understanding of the conditions that must be fulfilled. This done, the subject of the proper location of the station can be taken up.

So far as its position with reference to the line is concerned, it is perhaps sufficient to say that, other things being equal, it should be as nearly central as possible.

In any given station, whatever its position, a considerable item of the running expenses will be labor, and this is virtually independent of position. The factor that should go farthest in determining the proper location is the availability of fuel. If it is possible, the power-station should be so placed that coal cars can be run up to its very door and the fuel shoveled directly into the coal bins. In some few favored places an arrangement even nearer the ideal has been found possible, as, for example, in Scranton, Pa., where the street railway power-station is located just at the foot of a gigantic pile of culm, refuse from the neighboring coal mines, so that the fireman could almost climb up the side of the pile and kick the fuel under the boilers. Under such circumstances, especially as the culm is secured at a nominal price, the cost of fuel

is almost negligible. Ordinarily, however, one must depend on the railroads for the transportation of coal, and hence it is most desirable to place the station close beside a railroad track, even if the site be rendered somewhat more expensive by so doing. If the coal has to be carted at all, a few hundred yards more or less distance makes very little difference, as the expense is largely in the handling.

Aside from fuel, water is the next prime necessity to be considered, and it goes without saying that if a site can be found close both to railroad tracks and water of suitable quality for use in the boilers, the station should be placed there, even if at a considerable distance from the point that would be indicated by consideration of the line alone. In small stations, where condensing engines are not to be employed, the matter of water-supply becomes somewhat less important, but still deserves careful examination. If water for condensation is required, it is almost imperative to get within pumping distance of a plentiful supply.

In locating a railway power-station, then, the first thing to be considered is nearness to the supply of fuel, and after that, central position with reference to the line and availability of water.

In finally determining the best location for a station nothing but actual expense estimates will enable a decision to be formed. If the station is placed far away from the centre of the system, additional copper will be needed in the line to compensate for its increased distance, but to offset this there may be the gain that comes from cheaper fuel and water. Of two sites, one convenient to the supply of fuel, the other at the centre of the system, there will probably be a marked difference in the cost of the real estate.

If, to obtain cheap fuel, it becomes necessary to move the station so far from the centre of the

system, that the interest on the increased amount of copper necessary, is greater than the probable annual saving in fuel, it is sufficiently obvious that it will not pay to put the station near the fuel-supply. The relative cost of real estate in the two places must also be taken into consideration; it often happens, however, that a position at some point near a railway track, where cheap fuel can be obtained, is also a location where real estate is not unreasonably expensive; while the centre of the system is quite likely to be near the centre of the town, where land is decidedly costly. In choosing between two possible sites for a station the interest on real estate at the two points should be considered, as well as the interest on the investment in copper and the saving of coal. A few rough estimates will show the more economical location. In the majority of cases it is possible to get near coal and water without getting very far away from a reasonably central position on the line, but now and then the question becomes more complicated and recourse must be taken to the estimates just mentioned.

It may here be well to take some notice of the use of water-power. It is not under all circumstances that the water-wheel can successfully compete with the steam-engine, and the question should be determined on its merits in each particular case where it arises. Estimates should be made of the cost of installation of the wheels and the necessary waterways to feed them; the cost of water rights should be found, and the approximate amount of extra loss entailed by the generally more inconvenient location of the power-station.

It must be borne in mind that, particularly in a small station where the variations in load are excessive, water is by no means easy to regulate; and the greatest care should be exercised in the installation for the purpose of securing uniformity of speed, even under the large changes of

output required. This irregular output, which is a prominent characteristic of most electric-railway plants, in contradistinction from every other sort of installation, is a thing which should be most watchfully considered in designing future stations.

It is hard, even by diagrams, to give any adequate idea of the changes of load to which a small railway plant may be subjected; they are extraordinarily great and exceedingly sudden.

The effect of such a state of affairs is twofold: First, the regulating power of the machinery is taxed to its utmost, and even the best governed high-speed engines do not respond quickly enough to keep the voltage on the line constant under such circumstances, while the water-wheels are totally unable to keep pace with changes so sudden. Second, owing both to poor governing and great variations in actual mechanical strain, the machinery, whatever it may be, is subjected to severe and unusual tests of its strength and stability.

It therefore becomes necessary that in a railway power-station the foundations, engines, shafting, and dynamos should be of the best mechanical construction. The use of heavy fly-wheels on the engine or the shaft of the water-wheel is to be recommended, especially in small stations; and all engines, designed for this class of work, should be exceptionally strong and solid in construction and most securely bolted to an unusually firm foundation. The same is true of all shafting that is to be employed, and the dynamos should be fixed in position as solidly as possible. On extended street railway systems, running a considerable number of cars over a comparatively level track, the variations in load are of course much less, and consequently such extraordinary care in station construction becomes unnecessary. But in these, as in all similar cases, it is best to err on the side of safety.

Not only should this condition of variable load, that we have mentioned, affect the mechanical design of the station, but, to a certain extent, it should also modify the general arrangement of the plant with reference to the location of the various portions of the machinery. Especially is this true in small stations where only one engineer is employed.

It is most desirable, under such circumstances, so to place the engines, switchboard, and dynamos that they can be readily seen and their performance watched from a single point. If, for example, lightning enters a station, and one of the dynamos begins to blaze at the commutator, the engineer ought to be able to reach the switches, without rushing the length of the dynamo room and around various portions of the machinery. If a fuse blows, it ought to be in such a position as to be readily noticed, without going around a corner to look for it. In large stations, where several men are constantly employed, the necessity does not become so imperative.

With respect to the general design of a railway power-station, marked differences must necessarily exist between small and large installations.

As a general principle, it is safe to say that the subdivision of power should be carried rather further in railway plants than is ordinary in the construction of an electric-light installation, for the reason that the various component parts generally being subjected to far greater strains, and worked at a point much farther from their normal capacity, both security against accidents and general economy demand rather smaller units of power than in cases where the load is, relatively speaking, uniform and somewhere near the full capacity of the machinery. A fundamental law of economy in installations of any kind is to work at all times as near the full capacity of the machines employed as considerations of safety will permit. Dynamos and engines are

both designed to carry their normal rated loads economically and continuously, and while, in most power-stations for railway work, the great variations require a somewhat larger factor of safety, between the normal and maximum load, than in the case of electric-light work, the same broad idea must govern the arrangement of the plans for either.

In beginning the task of designing a railway power-station, the first problem is to decide on the amount of power to be required, both for present needs and future exigencies. Neglect of looking forward to the possibilities of a few years hence has caused inconvenience in many an electrical installation. On the other hand, construction for the distant future period when traffic will be several times its present amount is certain to produce an inefficient station.

The best policy is to build at first fully up to the immediate capacity anticipated, leaving the design of the station in such form that additional engines and dynamos can be installed whenever needed. If a fairly good estimate is made for the initial requirements, the plant can be increased at a rate quite sufficient to keep pace with any probable demands. It is worth noticing too that, if the number of cars on a given line is doubled, the maximum capacity of the plant is not increased in anything like the same ratio, unless in cases where very large numbers of cars are involved. If, for example, an electric road starts with twenty cars and provides ample equipment for them, the addition of twenty more will certainly not require doubling the capacity of the engines and dynamos; for as the number of cars becomes greater the average output demanded comes more nearly to approximate the maximum load, without very much increasing the latter.

Where only three or four cars are in use it is quite possible that all the motors may be making

severe demands upon the station at the same time; for example, two cars may be on heavy grades at the moment that another is starting, but with forty or fifty cars the varying amounts of power used by the several motors tend to balance each other, and it is safe to assume that, even with a ten-car line, at no time will all the motors be working simultaneously up to their full capacity.

So, in deciding on the proper capacity for the plant to be constructed, a very important factor is not only the size of the road, but its size with reference to the maximum output that the conditions of service will require.

Not only do these conditions go far to determine the proper capacity of the various prime movers employed, but, in the case of steam-engines at least, they afford good reasons for selecting one or another type of machine.

In the case of very small roads, the choice is limited to high-speed engines with a wide range of cut-off; of these the types on the market are almost too numerous to mention, and most of them give excellent performances. As the size of the road increases and the ratio between maximum and mean loads approaches unity, a point will be reached where it will become possible to employ economically large compound engines, with Corliss or equivalent valve gear. Condensation, even in small engines of all classes, should be practised wherever water is available, unless fuel is extremely cheap.

With very large stations, triple, and even quadruple, expansion engines are coming into use and do admirable work. It is hardly probable in any practical electric road, however, that so good economy can be obtained with these complex machines, as is usual when they are employed for other purposes, where the load is far more regular.

If we were, then, to attempt to obtain a general idea of the kind of engine suitable for any given station, we must be able to predict, roughly at least, the ratio between maximum and mean loads. In a general way, whenever the former is about three times the latter, nothing will give better results than a plain, solid, high-speed engine with a heavy fly-wheel; when the maximum load is about double the mean load, the various forms of Corliss and similar engines come into play with excellent results; and where the load ratio approaches even more nearly to unity and the road is of considerable size, requiring 500 horse-power or over, it is probable that the best results will be obtained by using triple-expansion engines. These are only approximate figures, but they at least give an idea of the circumstances that should cause the selection of one sort of engine rather than another.

Perhaps the best insight, into the methods to be followed in laying out a power-station for an electric road, may be obtained by considering plans for several plants, of particular sizes, and the special circumstances that lead to their adoption in each case. We shall select, then, three specimen cases, and investigate them in considerable detail. First, we shall take up a five-car road of average character; second, one with twenty-five cars or thereabouts, and finally, a large city system with one hundred cars in regular service. These three cases may fairly serve as examples by which to show the various conditions, that have to be met in designing a permanent and efficient power-station.

Let us suppose, in the first place, that the problem before us is to instal in a town of ten or fifteen thousand inhabitants a small electric road, not, as will be the case in larger places, for the purpose of enabling the business streets of the city to be reached from the suburbs, but to facili-

tate transit from one part of the town to another. The track will probably be less than five miles in length and usually a single track with turnouts.

The grades, of course, are liable to be of almost any amount, depending on the configuration of the country; but, as a rule, no continuous grades of more than six or seven per cent. are likely to be encountered, although there may be short pitches of slightly heavier gradient — nothing, however, of sufficient length to require particular consideration. On most small roads of this sort the service is rather infrequent, the cars being run on from fifteen to thirty minutes' headway, and five cars will generally be enough to give ample accommodations.

Starting, then, with the assumption of our five cars operating over not more than five miles of track and over grades of only moderate severity, the question that must be considered is, the character and size of the power plant required. In such situations the cars employed are, for the most part, sixteen or eighteen foot bodies on six-foot wheel bases; these have sufficient capacity for the work, can be employed to draw trailers if necessary, and are of reasonable weight.

It may be useful here to give a brief table showing approximately the power required to drive a sixteen-foot car weighing, with its equipment and a moderate load of passengers, five tons, up grades from one to ten per cent., at the uniform rate of eight miles per hour, which is not very far from being a fair average. On very light grades the determining factor of the power required is the condition of the track, and on very well-laid track the so-called "coefficient of traction" should be fifteen or sixteen pounds per ton; on ordinary street-car track it is more frequently twenty, and rises from that figure to twenty-five, thirty, and in some cases even to forty pounds

per ton; twenty pounds is quite nearly correct for the average conditions, and the table is founded on that assumption.

Per cent. grade.	Power at wheels.
0	3.5
1	6.5
2	9.5
2	13.0
4	16
5	19
6	22.5
7	25.5
8	28.5
9	32
10	35

This table gives the mechanical power required at the car axle, to the nearest half horse-power.

The average commercial efficiency of the motors is to be taken at the figure that is to-day true for most of those in use, of about 60%. To a very considerable extent grades compensate themselves, so that their effect on the *average* power required is not by any means so great as upon the *variations* in the power. Heavy grades mean a widely fluctuating maximum load, but they increase the average daily output of the plant by only a comparatively moderate amount.

With the ordinary car equipment of two 15 horse-power motors, and the usual speeds, from eight to twelve miles per hour, experience has shown that five to six electrical horse-power per car is necessary on nearly level track.

On large roads, where the times of abnormal output are infrequent, one can safely count on the figure just given for the power required per car; under such circumstances about ten indicated horse-power per car, at the station, will therefore prove quite sufficient. On a road like the one we are contemplating, with possibly severe grades and only five cars in operation, it may

easily happen, for example, that a couple of the cars may be simultaneously upon the grade and a third starting under somewhat unfavorable circumstances. The amount of current ordinarily taken in starting a car is momentarily more than fifty amperes, which at the ordinary voltage corresponds to about 25,000 watts; we therefore might have 80 or 90 horse-power demanded for a minute or two, and a longer call for power of 50 to 75 horse-power, depending of course on the length of the grades which are to be surmounted.

In towns where there are small roads such as we are considering, it frequently happens, too, that inordinate demands for power are made on the occasion of a somewhat infrequent theatre night, a political demonstration, a baseball game at some point far out on the line, and other public gatherings. This usually means bunching three or four heavily loaded cars, sometimes all the cars on the line, at one point, and starting them out within a minute or two of each other: for a small road is dependent for its revenue largely on its willingness and ability to accommodate just such unusual demands.

It would therefore probably happen that on our five-car road there would be times when the output would have to reach nearly or quite 100 horse-power for a few minutes at a time, although it would be strange if the *average* electrical horse-power required throughout the day should exceed 30. The reader will therefore readily understand that, under the circumstances supposed, a far greater margin of power is required than in the case of a larger system.

The station should be located as centrally as feasible, and close alongside a railway track or wharf, where coal can be easily obtained. It is highly desirable, even in so small an installation, to have a spare engine and dynamo, although it is frequently impracticable; it may be laid down,

however, as a rule of fundamental importance, that a road should never be trusted to a single dynamo for continuous running, and even if the total output required be small, two dynamos should be employed: for nothing damages the reputation of a street-railway system more permanently, than a breakdown that requires the suspension of traffic for a day or so, and such breakdowns are sooner or later bound to occur where only a single dynamo is used. Railway generators are peculiarly susceptible to injury from lightning, and for this, if for no other reason, the above precaution is necessary. For our specimen five-car road, a proper outfit of dynamos would be two of about 40,000 watts rated capacity each; this means an ability to supply 100 electrical horse-power, or more if necessary, and sufficient capacity in either dynamo to keep up a tolerable service on the road if its mate should unfortunately be disabled.

As regards the type of engine that should be employed there is little room for dispute, for the only thing that would answer the purpose properly is a high-speed simple engine, belted direct to the generators, and having as much weight in frame and fly-wheel and as wide a range of cut-off as is practicable. If it can be run condensing, so much the better, as in most cases of employing steam-engines. Its capacity should be, approximately, 80 indicated horse-power at one-quarter stroke cut-off and 90 or 100 pounds steam-pressure.

It will be observed that the rated capacity of the engine of this plant is much less than that of the dynamos; and this is the correct arrangement, for a dynamo can be run at half its nominal output without serious loss of efficiency, while under similar circumstances an engine not only loses from its friction becoming a large portion of the total output, but the machine *per se* becomes less economical of steam.

The boilers, for the plant, should be quite easily capable of supplying steam for 100 horse-power and rather more if pushed a little. Two boilers should be employed, to permit giving them the most careful attention. A single boiler is undesirable for the same reason as a single dynamo. It is even better to have two boilers — either of them sufficiently large to handle the plant if necessary — and employ them alternately; this principle, although more expensive in first cost, is cheaper in the long run.

We have, therefore, for this first specimen station, an equipment consisting of two 40,000-watt dynamos, one 80 horse-power high-speed simple engine belted directly to them, and two boilers of about 50 nominal horse-power each.

The foundations are a matter of prime importance; both engines and dynamos should be given a most solid bed constructed of rubble and cement, or brickwork, as convenience dictates, but far more substantial than would be employed in supporting ordinary machinery. The dynamos ought to be carefully insulated, the wooden base on which they are usually placed being generally sufficient for this, provided proper foundations are employed. The interior fittings and switchboard ought to be the subject of careful, thorough construction; for no money is saved by cheap and hasty work about a station. Lightning arresters and the like should be given non-combustible bases of a size large enough to avoid danger of any woodwork catching fire in case of accident. The usual insurance rules for electric installations will serve as a sufficient guide for putting up the subsidiary apparatus.

Passing now to the next case to be discussed, let us consider a road employing in the neighborhood of twenty-five cars for regular service, and situated in a thriving city of a size sufficient

to give a reasonably heavy traffic. Let the grades be about as in the former case and the cars be of similar type.

For roads operating from five to twenty-five cars, probably no better arrangement could be devised than an amplification of the system just suggested, employing as the system increases two or three engines and four or six dynamos, and allowing from 12 to 18 normal indicated horse-power at the engines, according to the size of the system and the severity of grades. Compound engines may be used with great advantage for machines of 100 horse-power and upward, especially if it is possible to obtain water for condensation. As for a 25-car road, it is on debatable ground, where a question necessarily arises between the slight economy to be gained by direct belting and the great convenience of being able to operate any and all the dynamos from either of the engines. At about the same size of plant, too, the low-speed engine begins to come into play.

For a road of the size we are considering, an allowance of 10 or 12 indicated horse-power per car would nearly always be sufficient, and a proper equipment for twenty-five cars will consist of four 60-kilowatt dynamos. When long cars or snow-sweepers are used, each should be reckoned as equal to two ordinary cars. It is probably preferable to have recourse to a counter-shaft, which should be situated at one end of the dynamo room and on very substantial foundations. The dynamos should each be driven from a pulley provided with a friction clutch, so that any of the machines may be employed. The shaft itself should be divided into two sections, connected to each other and to the engines by friction clutches.

With an installation of this size two engines should always be employed, belted direct to

driving pulleys at the ends of the line shaft; these engines should be of similar or identical pattern, and may be either simple or compound, as the conditions of fuel expense may dictate. Corliss or similar low-speed engines may very well be used under these circumstances, as, except in certain cases, the fluctuations of load are not likely to be great enough to put such an engine at any considerable disadvantage. With slow-speed engines, either simple or compound, a rated capacity of 150 horse-power is desirable for each. If high-speed engines having a wide range of cut-off are employed, 125 horse-power nominal capacity for each will probably be sufficient. The boilers should be three or four in number, aggregating about 300 horse-power. In operating the plant, a little judgment will enable excellent results to be attained. During a large part of the day one engine operating two, or possibly three, of the dynamos will handle the load easily and evenly; in the morning and the evening, and at times when especially heavy work is required, all the dynamos and both engines can be put into use. Under these circumstances, repairs on the engines or dynamos are easily carried out without interfering seriously with the regular service of the road. If compound engines are used, they should be worked condensing if possible. The cross-compound type is probably preferable to the tandem patterns, in the matter of ease of repairs and accessibility, although some of the latter do excellent work. The fly-wheels in any case should be of unusual weight — at least 50% heavier than would be employed in driving ordinary machinery. For roads operating over twenty-five cars, an amplification of the plans just given works admirably, the size of engines and dynamos being increased to meet the larger output required.

Taking up the case of a 100-car road, something of the same line of equipment may be

followed, but the dynamo units should of course be larger. For one hundred cars six 150-kilowatt machines are desirable, allowing a sufficient surplus of power to reserve one dynamo as spare equipment. The same arrangement of the line shaft may be advantageously followed. It is probably advisable, however, to divide it into three sections instead of two, providing, as before, friction clutches for each dynamo pulley and each driving pulley. Usually two or three engines may be used, preferably three, as this number enables a better adjustment of the load and permits one of the engines to be thrown out of use for repairs without causing serious inconvenience. For so large a plant, triple-expansion condensing engines are very strongly to be recommended; three of 400 nominal horse-power each would answer the purpose admirably. Under these conditions the mean load can be kept reasonably near the full output of the machines in use all the time.

Except for a few hours each day, two engines will do the work and do it well, and one dynamo could be, and should be, reserved to be thrown in only when it is absolutely necessary. Slow-speed engines, with Corliss or equivalent valve gear, are in their element in an installation of this size; and all the great advantage of their unusual efficiency can be enjoyed. The boiler capacity, aggregating say 1,200 horse-power, should always be divided into five or six units, so that the boilers can be thoroughly overhauled, one at a time, without causing any special inconvenience.

In a road of this size it is decidedly advantageous to employ some double-truck long cars, with two motors of 20 horse-power or thereabouts; and these should be counted as the equivalent of two standard cars in making up the total equipment. On small roads such cars are not advis-

able, as they are very heavy and would have to be run very lightly loaded a large part of the time; but as the size of the system and the traffic increases, their use becomes considerable, as is the case whenever high speed is to be attempted.

In unusually large electric-railway installations, operating several hundred cars, it may be advisable to employ an arrangement radically different from the one just mentioned — that is, very large low-speed dynamos, coupled or belted directly to triple-expansion engines, forming a combination plant quite similar to that now generally used for ship lighting, but on an enormously larger scale. The advantages to be found in this description of plant are, first, a saving of power of perhaps 5%, owing to dispensing with the countershaft and belting; and, second, compactness, an advantage not to be despised in large cities, where land is exceedingly expensive. The disadvantages are those that always attend the use of a comparatively small number of machines; for, in case of accident, a considerable fraction of the plant might be rendered for the time being unfit for use, thus interrupting the service. Unless the size of the installation is so great that five or six 300 or 400 horse-power dynamos are required, the arrangement of countershaft that has just been described will doubtless be found preferable, for it enables any or all of the dynamos to be run from any engine or combination of engines. This secures not only immunity against breakdown, but also enables the load to be readily adjusted so as to keep the engines and dynamos actually in use nearly up to their full output, and consequently operating at their best efficiency.

A good many of our present electric roads have employed, for a service aggregating as high as one hundred cars, merely an exaggeration of the plans just laid down for the roads of the

smallest size, some few designing engineers having carried the subdivision of power to a very needless extreme. If the conditions of high average load are fulfilled, such systems as those just mentioned may work very economically; but it is believed that, with equal care, the designs we have shown will produce somewhat better results in economy of fuel, continuity of service, and small repair bills. As regards the subdivision of power, one general rule may safely be laid down, deviation from which is very likely to lead to high running expenses or disastrous uncertainty of service; it is this: *The number of power units should be just such, that the disabling of one of them will not interfere with the successful operation of the system.* It will very seldom happen that more than a single unit, composed of an engine and dynamo, or engine and two dynamos, will be disabled at the same time. Owing to the fact that accidents are rather more likely to happen to dynamos than to engines, the engine units may be larger than the dynamo units. In very small plants it becomes necessary sometimes to take one's chances of being crippled by an accident, but every station should be so designed that an engine or dynamo can be stopped for repairs at any time, without seriously interfering with the car service.

Hints for the Care of Railway Power-stations.

(From Crosby & Bell's Electric Railways.)

For the benefit of those who have to do with the running of stations, a brief series of hints on the special care that must be given to station apparatus is here given.

Boilers.

To begin at the boiler room, it is almost unnecessary to state that scale is the fireman's worst enemy. Boiler scale is the natural and logical result of insufficient attention to the boilers. All water holds in solution a certain amount of mineral matter, varying from the merest traces — next to none at all — to quite a perceptible fraction of an ounce per gallon, in mineral waters. Hard water, so called, is that which contains an unusual proportion of mineral matter, most frequently salts of lime.

During the process of evaporation that goes on in the boiler all this material is left behind, and unless the boiler is periodically cleaned out a deposit, calcareous in nature and sometimes almost as hard as stone, will be formed wherever the water touches the iron shell or tubes of the boiler.

In addition, there is likely to be a certain amount of suspended matter in water — particularly river water — which is added to the general collection of foreign matter and is likely to coat the interior of the boiler with mud. Boiler scale a quarter of an inch thick and nearly as hard as

flint has often been known to have been taken from boilers; and, in fact, it is only too common to find scale allowed to accumulate through carelessness, although seldom to so great an extent.

The result is not only to diminish very much the evaporative power of the boiler, but to expose the iron, unshielded by circulation of water from the effects of direct heating, in such a way as to rapidly deteriorate it and very likely to cause a boiler explosion. The remedy for scale is to periodically clean out the boilers thoroughly and carefully, and to use from time to time suitable scale preventers, which usually act mechanically by hindering the scale from sticking to the iron. A large number of these are in use, and perhaps the simplest of any is crude petroleum, a small amount of which is placed in the bottom of the boiler after it has been thoroughly cleaned and before the water is turned on; as the boiler fills, its interior is coated with a film of oil which does not allow the hard deposit of scale to cling.

No general rule can be laid down as to the frequency of boiler-cleaning necessary, for it depends entirely on the quality of the water used. A very little experience will enable an engineer, under any particular circumstances, to tell in what quantity deposit is forming, and to apply the proper remedies at once.

It should be the engineer's business to see that the boiler-room accessories are kept in proper condition, that the safety-valve is all right, the steam-gauge registering correctly, the joints tight, and the pumps in working order. Duplicate means should invariably be provided for feeding the boilers, for one of the most serious accidents that can happen is the derangement of the feeding apparatus so that water cannot be properly fed into the boilers. If injectors of the Körting or any other type are employed, a steam-pump also should invariably be supplied; and even if but

seldom used, it should be tested at frequent intervals to see that it is kept in perfect working order against the time, which must inevitably come, when the injector gets clogged and refuses to do its duty. All steam-pipes of any length should be jacketed with some one of the many non-conducting coatings now in use — magnesia, asbestos, mineral wool, or the like.

Engines.

With respect to the engines, one general rule may be laid down: watch their performance and overhaul them at the first sign of trouble, for trouble goes on from bad to worse with the greatest speed.

A well-made, well-set, and well-cared for engine is as reliable a piece of machinery as the ingenuity of man has yet devised, but, if ill-treated, even the best engine will go on strike with extraordinary persistence. As previously mentioned, the foundations for engines to be used in railway power-stations should be extra heavy, and the engine itself thoroughly well balanced. There should be very little or no vibration when the machine is running, either in the engine itself or in the steam-pipes. If the engine is regularly indicated, as it should be, the valves can be put in their proper order very readily, and any abnormal features about the engine noted at once. Any thumping, rattling, or unusual irregularities in the running of an engine should be investigated at the earliest possible moment and the proper remedies applied. It is impossible here to go into the details of running an engine, but these general cautions are given — rendered all the more necessary in railway power-stations on account of the severe strains to which the machinery is sometimes subjected.

Dynamos.

The list of faults to which a dynamo may be subject varies somewhat with the size and character of the machine; and what applies to small motors, or to arc-light dynamos, is not likely to apply with equal force to railway generators. These latter are usually very well made and efficient machines, as, indeed, they have to be to perform the severe service exacted from them.

As regards their general arrangement, they should be on firm foundations, readily accessible, and provided with means for loosening, tightening, and aligning the belts. First of all, they should be kept clean and dry, and usually, if well cared for, will give very little trouble. However, every dynamo is liable sooner or later, from one cause or another, to operate in a somewhat unsatisfactory manner. Whatever the cause of such abnormal performance may be, it must be hunted up and the proper remedy applied at once.

Speaking in a general way, the troubles most likely to be met are sparking, heating of the commutator, armature, or field magnets, heating of bearings, or failure to generate current at all; this last is unusual, and the cause may be either very serious or very trifling. Of course, several of these "bugs" often develop at once, as, for example, a prolonged overload is likely to cause sparking, and heating of the commutator, armature, and bearings.

Taking, however, the causes mentioned in their order, we may note that sparking at the commutator may be produced by a rather wide variety of causes. The commonest one — so common as hardly to require comment — is a combination of overload and wrong position of the brushes; the former, a glance at the ammeter will tell, and in addition it becomes manifest by overheating

of the armature, severe strains, and sometimes even slipping of the belt; the latter cause can be remedied by moving the rocker arm to the point of minimum sparking.

In the earlier railway dynamos it was quite common to find a sudden variation of load requiring a considerable change in the position of the brushes; in the later types, however, little or no change is necessary, and whether the current is one ampere or several hundred, the brushes can be left very nearly in the same position. On a dynamo where the non-sparking position of the brushes does shift, eternal vigilance is the only way to avoid sparking at the commutator.

The cause of sparking just mentioned presupposes that the machine is in good condition, but it is not altogether uncommon to find sparking produced by faults either in the commutator or in the armature. If the former is eccentric, irregularly worn, or has one or more bars loose or set irregularly with respect to the others, sparking is sure to ensue; for the tension on the brushes is irregular, they are thrown into vibration, and the result makes itself evident at once. An examination of the commutator will readily detect these defects. A rough commutator needs no description; and if it is eccentric, the fact can be readily detected, either by a visible wabbling or by holding a stick lightly against its surface, when any irregularity in motion will make itself apparent to the sense of touch. Loose or irregular bars are found with equal ease.

In these days of carbon brushes, worn commutators are not so common as they once were; if from using copper brushes and keeping them in the same position too long the commutator should become untrue, it should be smoothed very cautiously with a fine file, or very fine sand-paper — never emery-paper — great care being taken to brush the minute particles of metal out of the insulation between the commutator segments before starting up the machine. In very bad cases,

a thin cut taken off the commutator in a lathe will remedy the difficulty; but this is considerable trouble, and on some large machines a tool-holder is arranged to be fitted alongside the commutator, so as to turn it down very easily by simply running at low speed and feeding the tool by hand. Similar in its results to a rough commutator is a rough brush. A little examination will show when the brush is irregularly worn, so as to make poor contact, and, if so, it should be trimmed or ground down.

Sparking due to faults in the armature may be very severe, but is almost invariably local in its character; that is, affecting only a few of the commutator segments. This peculiarity is very readily noticeable, and such an effect may be due either to a short-circuited coil in the armature or a broken coil, either one of which will produce violent sparking at the commutator bar or bars most immediately concerned with that particular coil. When a coil is short-circuited it heats violently, or may burn out entirely, and is quite likely to make itself obvious by a smell of overheated insulation. On running the machine slowly the current may show pulsations, and on stopping, running the fingers over the armature will generally locate the short-circuited coil immediately by the heating, particularly if one is guided to it by the visible burning at the edges of the corresponding commutator segments.

Short circuits may occasionally be produced by stray particles of metal getting between the segments of the commutator or among the armature connections. Under these circumstances the trouble can be found by inspection and easily removed. More often the short circuit is in the coils themselves, and may usually be looked for at the head of the armature.

Perhaps the most elusive of all faults in armatures is what may best be described as a flying

short circuit — that is, a short circuit between two or more of the armature coils of such a character that it does not appear when the machine is at rest, but becomes noticeable as soon as the revolution of the armature, by centrifugal force or magnetic drag, presses the offending wires together. Under these conditions the machine may fail to excite, as the shunt winding is completely short-circuited; there will be little or no heating, because of the small excitation and little current flowing in the coils; and oftentimes even a careful measurement of the resistance of the armature coils all around the commutator will fail to disclose the trouble, for the simple reason that when the armature stops the short circuit no longer exists. Such a fault is perhaps best found by separately exciting the fields and then running the machine rather slowly, when all the characteristic signs of short-circuited coils will appear and can be located by the consequent heating.

If there is a broken circuit in the armature, as sometimes happens, there will be very serious flashing at the commutator — localized as before — but there will be no special heating of a single coil. The defect may be sought at the commutator end of the armature, as breaks in the wire are most frequent where the connections are made with the commutator segments. In either of the cases we have been discussing it is best not to try any makeshifts, but to cut the machine out until it can be properly repaired. A temporary remedy sometimes applied in such a case is to cut off the defective coil from the commutator bars with which it is joined, and then temporarily to connect the disconnected bars to those next succeeding; but it is not advisable to do this unless driven to it.

In addition to the causes of sparking already enumerated, there is a tendency for sparks to flash around the commutator over several segments. This is most often observed where carbon

brushes are used, and is usually a result of carbon dust getting into the insulation between the segments and over the surface of the commutator generally. It is often accompanied by heating of the commutator, and never occurs where proper care is taken.

Heating in either the field-magnet coil or the armature of a dynamo is generally due to one of two causes — overloading or short circuits; overloading can be told by the condition of the ammeter, and most often results in railway power-stations from a ground on the line, although the fuses will usually take care of the machines. The heating due to short circuits in the armature we have already mentioned. In addition there may be — particularly when the machine is first set up — moisture in the armature coils, producing a general case of short circuit through the insulation. Where this is present the armature usually feels moist, and may even steam. It is a rather unusual condition, however, and can be best remedied by drying the armature very gently for a considerable time.

Passing a current through it is the easiest way to do this, although the amount used should not exceed the regular current for which the armature is intended.

Heating in field-magnet coils may arise from forcing the voltage, and thus sending through the coils a greater current than that for which they were designed; or from a genuine short circuit in the coils, though not a usual occurrence, and one easily discovered by measuring the resistance of the two or four coils with which the machine is wound and comparing them each to each. If the difference in resistance rises to more than a few per cent., there is probably a short circuit. Moisture may get into the field coils just as in the armature, and is expelled in the same way.

Heating of the commutator may be due to general overload, or to short circuits between the

segments, due usually to particles of metal or carbon from the brushes. The first case may be detected by the ammeter, the second by the localized heating and the sparking that ensues. Cleaning very carefully is the only suitable remedy.

One of the commonest troubles encountered in an electric station of any kind is the heating of the bearings in one or more of the dynamos; this is generally due either to lack of oil or to excessive pressure coming from an overload. With the ordinary types of railway generators, in which the bearings are self-oiling, there is little likelihood of the first cause producing any serious results, unless the oil-well leaks or is extraordinarily neglected; and a glance at it will tell whether the trouble is to be sought there. Occasionally the armature shaft may be sprung, or the bearings may be out of line, although neither of these conditions is common. In the former case, the armature turns hard and is likely to stick at a particular point; in the latter, the shaft still turns with difficulty, but with nearly equal difficulty all the way round, and the revolution becomes much easier if the bearings are slightly loosened from their foundations. There is no help for a sprung shaft, while the bearings, if out of place, can be aligned. Neither of these difficulties is as common, however, as a hot bearing, due either to the pressure of the shoulder of the pulley sidewise against the bearing, or too great belt tension.

In either case the bearing on the pulley end will be heated more than the other. If the trouble is due to lateral thrust, — as can be easily told by trying to push the armature back and forward in its bearings while the machine is running, — the belt pull should be aligned. Lateral play of half an inch or more is allowed on almost all dynamos, so that with ordinary care there need be no trouble from this source.

If the heating is simply a case of too great belt tension, which can generally be told by inspection, the only thing to be done is to ease the belt; the trouble is unlikely to occur at all if the bearings are looked after and kept in proper condition. The greater the area of contact on the pulley can be made, either by using a larger pulley on the machine or a smaller one on the driving shaft, or by using wider pulleys and belting, the more easily the same power can be transmitted, with less pressure.

It is not a good plan to try to cool dynamo bearings with water, for water is not a pleasant thing to have in the vicinity of an armature; better cut out the machine until it can be fixed, or, if it be absolutely necessary to run, the very careful application of ice may sometimes relieve the difficulty.

Occasionally a dynamo will positively refuse to do its work; and perhaps the most frequent causes are a flying short circuit in the armature, such as has just been mentioned, or a break or bad connection in the field coils. If the former is the case, separate excitation by one of the other machines will soon locate the trouble; if the latter, measuring the resistance of the field coils will generally disclose the difficulty. Sometimes in setting up the machine an accidental bad connection may pass unnoticed until an attempt is made to run. If a dynamo has been assembled recently, there may be a bad magnetic joint between the yoke and the magnet cores, and the machine will fail to excite properly. This will be found by inspection, and it is remedied without difficulty by doing the work over again more carefully.

Setting up or taking down a dynamo is a rather difficult matter, and in a permanent station it is a very good idea to have a simple traveling crane for the purpose of doing such work as may

be required. Where this does not exist, temporary supports can be erected and a differential tackle will do the work. If the traveling crane is at hand, the removal of an armature becomes a simple matter, for its weight can be taken by the tackle and it can then be slipped out of position by a single movement of the crane; the yoke or other attachments which may be in the way being previously removed. Such a course is only necessary in very large armatures, for small ones can be easily handled by a gang of men, the shaft always being so blocked up as not to bring the armature down on the pole pieces. In shifting an armature with the crane or temporary tackle, the ropes and chains should never be allowed to touch the windings; the gripe should be entirely on the shaft.

Minor Apparatus.

As regards the subsidiary apparatus required to run a station, every switch, cut-out, and lightning arrester should be kept in thoroughly good working order, with no bad contacts and no dirt allowed to accumulate. Lightning arresters should be set with the plates or points across which the lightning is expected to jump very close together, from a sixteenth to an eighth of an inch, and should be kept free from dust, which might otherwise cause a short circuit. Generally only those forms should be used in which after one lightning discharge the arrester is automatically reset and ready for another.

The measuring instruments of the station should be compared now and then with each other and with standard instruments, and the engineer or superintendent of the station ought to take pains to understand the function of each piece of subsidiary apparatus, of whatever kind, with

which he has to do. Specific information in these matters can best be obtained from the company which furnishes the particular forms of apparatus employed, as there are frequently minor, though important, details peculiar to each especial make.

General Instructions for the Care of Railway Motors.

(From Crosby & Bell's Electric Railways.)

It should be well understood that it is as necessary to properly care for electric railway motors as that a steam locomotive should be kept clean and in good working order. Careful attention given to all the parts of any piece of machinery ensures longer life and better service. Electric-railway motors have a very hard duty to perform. Rough and dirty tracks, severe strains, heavy loads, etc., all tend to wrench and shake the motors to pieces, and it is, therefore, very necessary that every individual part of the apparatus should receive the most careful attention. In order that this matter may be well understood and emphasized, we have arranged a number of rules, which, if followed in their spirit, we believe will greatly aid those, to whom the care of motors is given, in keeping the apparatus in the best possible condition.

There are so many manufacturers making electrical railway apparatus, and these change so frequently, in greater or less degree, the details of their apparatus, that it is impossible to give to-day any set of rules which may not in considerable part be inapplicable within the next few months. It must always remain necessary that the more minute instructions required for the operation of apparatus, shall be obtained directly from the manufacturer of that apparatus.

We therefore call the rules given "General Instructions for the Care of Railway Motors."

A. Inspection of cars and their preparation for service.

The motors should be thoroughly cleaned and all oil, grease, dust, etc., wiped from them; all oil-wells and grease-cups should be filled. The armatures, commutators, and brush-

holders should receive especial care. An accumulation of dust and oil is a good inducement for short circuits. All parts should be kept as dry and clean as possible; a very little vaseline or paraffine on the commutator, however, if carbon brushes are used, lengthens the life of the brushes and seems to diminish the noise.

All nuts and bolts should be carefully inspected and seen to be tight and in their proper places. Keep the gearing as free from dirt as possible. Many motors now have their gears enclosed in an oil bath, which besides diminishing the noise keeps the gearing in very good condition.

Examine the wiring of the car to see that the connections are correctly and securely made and the insulation of the wires intact. See that the controlling apparatus is in good condition; this is very important, and too much care cannot be taken to see that all controlling mechanisms, switchboxes, rheostats, reversing switches, etc., are in the best possible working order. At least once a week examine and carefully clean the lightning arrester. Remove all oil and grease from the boxes, and carefully clean the bearings. Every fortnight examine the armature, fields, and insulation; repaint and reshellac if necessary.

The trolleys should also be inspected, and all bearings cleaned and properly lubricated — especial attention being given to the trolley wheel. There should be good contact between the wheel and "leading down" wires, otherwise there will be an injurious sparking at the wheel. The trolley springs should be adjusted so that the trolley wheel shall be pressed against the wire firmly enough to ensure a good working contact when running at full speed.

The brake mechanism in all its parts should be thoroughly examined, for it is exceedingly

important that this part of the apparatus be in good condition. Cars should be furnished with good sand if operated on hilly roads.

See that the car is supplied with a screwdriver, monkeywrench, etc., an extra lamp or two, and an oil lamp for use if the power should be cut off.

B. Operation of the cars.

1. When cars are left standing in the car-house or on a side-track, see that the safety or cut-out switches are placed so that the circuit is open. Generally there is some mark on the switch to show the proper position of the switch lever. The trolley wheel should be removed from the wire and left in such a position as to relieve the trolley springs of their tension.

2. Before placing the trolley wheel on the wire, be sure the circuit is open at the switches, and before closing the switches be sure that the controller handle is at the "off" stop.

Before placing the trolley wheel firmly on the wire, let the side of the wheel just touch the wire; if any flash occurs, except the spark which may be seen when the lamps are on, then something is wrong, and the wheel should be kept off the wire. Probably a switch which should have been open will be found closed.

3. If there is a reversing switch on the car, see that it is set properly before applying the power.

4. Before starting the car, raise the traps and see that the commutators, armatures, gears, etc., are in condition for work. See that the brushes and holders are in good order and properly placed.

5. When ready to start, move the controller handle gradually but firmly. If the car does not

move, throw the controller handle off and look at the several switches between the trolley wire and the motors. Probably some of them will be found open. If the car still refuses to move, throw on the lamp circuit. If there is trouble at the power-station, the lamps will tell the story, unless it happens that the dirt on the track prevents a contact between the wheels and the rails. If this is the case, press the switchstick between the rear of one of the wheels and the rail, thus securing a ground. On many roads, an insulated wire is furnished each car for use in just such cases as this.

6. Do not attempt to run the car backward unless the trolley is closely watched by some one who holds the cord in his hand.

7. In throwing power on, move the controller handle step by step, allowing the car to gain headway under one, before advancing to the next step. Too sudden starting strains the machinery and wrenches the gears, etc.

8. In throwing the power off, move the controller handle gradually until nearly at the "off" stop, when it should be turned the rest of the way with a snap; and care should be taken that the power is off before setting the brakes.

9. The brakes should be set gradually, so as not to bring an undue strain upon the gearing.

10. Never run downgrade faster than the maximum speed allowed on the level, and always keep perfect control of the car.

11. If the trolley jumps off the wire, a slight slowing of the car may be felt, and at night the lights will go out. In this case throw the controller handle to the "off" position and stop the car immediately.

12. When by accident or otherwise the current from the power-station is cut off, throw the controller handle to the "off" stop, throw on the lighting circuit switch, and watch for the power. When the power is on, it will be well for a portion of the cars only, say those having even numbers, to start immediately, the others waiting a minute or two. If all start at once, a severe strain may be placed upon the dynamos and engines.

13. Never stop a car on a curve, except in case of accident. This will save the gearing from unnecessary wear and tear, and at the same time relieve the generators and motors from excessive strain and resulting loss of power. Many breakdowns and troubles have resulted from unnecessarily stopping on curves. The extraordinary amount of current required to start a loaded car on a curve may endanger the insulation of the motors.

14. Never reverse a car while it is in motion, except to avoid serious accident, and then it must be done very carefully. It is very easy to overdo the matter, blow the fuses, and thus perhaps become helpless to avert some second accident.

15. If there is a reversing switch on the car, be sure that the power is cut off before throwing the switch.

16. In any case of reversal to avoid accident, turn the reversed power on very gradually, as a little will be found sufficient to stop the car quickly, while a sudden application of the power might strip the gears. Break the current as soon as the car stops.

17. Do not reverse a car with the brakes set, for the fuse may be needlessly blown.

18. Run slowly over railroad crossings, curves, switches, rough track, etc. Remember that the cars are heavy and that shaking up the motors should be avoided as much as possible.

19. Run through water very slowly and carefully, and in examining the motors be sure that no water drips from the clothing or elsewhere upon them. Water on the field magnets will soon cause them to burn out.

20. Be careful that nothing falls from the pockets on the motors, and do not let any metal — for example, an oil-can — touch the brass screws on the connection boards, or in any way cross-connect parts of the motor circuit unless the trolley is off.

21. Do not run over sticks, stones, or wires; they may be caught by or knocked against the motors. Remember that the motors are hung very low and are apt to strike such obstructions.

22. If a motor is flashing badly at the commutator, or gives out a burning odor, or shows weakness in any way, it is best to cut it out. Some companies provide switches to do this easily. If the car has a cut-out switch, insert the key which should be with it in the socket, with pointer up, and turn the pointer around one quarter of a circle toward the good motor. *Never attempt to move this switch unless the main motor switch is off.*

23. It may be that a fuse is blown, in which case try another, and then two in multiple, which will generally be sufficient for the necessary current required to start the car. If the double one blows, there is probably some unusual trouble with the car, which needs careful attention.

24. Unless very familiar with their current-carrying capacity, never put copper or iron wires in place of the lead fuse, for it is the function of this fuse to "blow" whenever the motors are endangered, and if a wire were used perhaps the current which it would allow to pass would damage the motors seriously.

25. A sure way to stop any electrical trouble in the car is to remove the trolley from the wire.

26. In case of a lightning storm, keep cool, for there is absolutely no danger. If the motors are damaged by lightning, the car will run unsteadily or stop altogether. If lightning damages one motor, cut it out. If both are damaged, pull the trolley down and wait to be pushed back to the car-house.

27. Never run downgrade with the current on, although the trolley should always be in contact with the wire on such occasions, as it may be necessary to reverse the car.

28. Be careful in the use of sand on the track, as too much will prevent good ground connections. A very small amount will serve to keep the wheels from slipping.

29. The power should be shut off when passing a "trolley break" or "section insulator."

30. In ordinary stopping of a car, always release the brake, but do not let it fly, just before coming to a dead stop. The armature will then be able to gather up the lost motion in the gears and shafting, and will be ready for a smooth start.

31. Do not attempt to make up time on grades or rough tracks; in fact, never try to make up lost time *at the expense of the machinery.*

32. Familiarize yourself with the peculiar noises made by the apparatus, in order that you may detect in this way whether the motors are acting properly.

The Return Circuit on Electric Street Railway Systems.

This subject is one which has not received the careful attention it should, from electrical engineers and contractors, or railway companies who have in operation or are about to install an electric railway system. The return circuit may be so constructed, that the coal consumption of the power-station will be largely in excess of that required to operate the road, and a large number of roads are now operating with power-house expenses frightfully in excess of what they should be, on account of poorly balanced circuits.

The following are the different methods that have been, and are now, in use, with mention of their advantages and disadvantages: The first method, the oldest, is that of bonding the rails with a number four soft-drawn, bare, copper wire about thirty-six inches in length, having a copper rivet, three eighths of an inch in diameter, soldered on each end. The manner of connecting is to drill a three-eighths inch hole in the rail about eighteen inches from the end, the rivet is passed through the hole, from the under side of the rail, and is headed down securely; in addition to this, the bond wires are connected together, about every 500 feet, with a copper wire of the same size as the bond wire, and all connections are carefully soldered.

The objection to this method is the great liability of poor connections, owing to the large number of soldered joints necessary to secure the rivets to the bonding wires, and the liability of the bonding wires of this size breaking by reason of poor joints in the track, or by teams running on the track where paving is not used, the vibration of track causing the wire to break

away from the rivet. Further, the ampere carrying capacity of this circuit is only sufficient for small lines operating a limited number of cars.

The second method of construction only differs from the first by the use of iron instead of copper wire. This method has only one advantage over the others; that is, the initial low cost. It is the poorest kind of a return, and after it has been laid for a few months is but little better than the track itself without bond wires. It is well known that the life of a number four galvanized iron wire when suspended in the air is about seven years, and its life when underground must be considerably less, on account of its great liability to corrosion. Bonding wires of copper are used to obtain high conductivity at the joints of the rail, which cannot be obtained by means of the ordinary plates and bolts on account of the rust which accumulates at these points; therefore it seems useless to construct the return circuit with iron wire, which has a conductivity considerably less than that of copper. The efficiency of the iron wire return circuit is considerably reduced by reason of the rusting away of the wires where they are connected to the rails.

The third method, one which has been generally used and has given good results in a number of cases, is to construct the return circuit in the same manner as in the first method, but in addition to this use a number zero soft drawn, bare copper supplementary wire, laid between the rails and connected to each bond wire, soldering all connections. However, the same objections apply to this as to the first method, with the exception of the addition of the number zero wire. On some roads of great length where a large number of cars are used, it has been found necessary to run out track feeders in addition to the supplementary wire, since the conducting capacity of

the rails can not be fully utilized when number four bond wires are used. Railway companies have often objected to using the supplementary wire on account of the increased cost of track construction, and have preferred to put that amount of money into overhead feeder lines, and in a great many cases this has been done, incurring a needless expenditure of money without benefiting the system one particle.

The Best Return Circuit.

The best return circuit is constructed in the following manner:—Drill in the rails, about eighteen inches from each end, a hole nine sixteenths of an inch in diameter, and connect to each rail a number zero soft drawn bare copper bond wire by means of a channel pin. Placing the bond wire in the hole from the inside of the track and driving the channel pin in from the outside secures it firmly to the rail without the use of solder. The cost of labor is also largely reduced, as the connection can be made in a very short space of time. In addition to this, the rails are cross-connected, every 300 feet, by means of a copper wire the same size as the bonding wires. The cost of this, including all material and labor, is about $300 per mile of single track, and as compared with the third method where supplementary number zero wire is used and which costs $550, a saving is made of $250 per mile, and in addition a much better return is obtained with far less liability of breaking of bonding wires or corrosion from poor soldering.

In addition to this, on roads of over five miles in length, an earth return should be used, constructed in the following manner:—At intervals of about a mile old car wheels are buried in the ground between the tracks, sufficiently deep to be always in moist earth. These are connected

to the rails by means of number zero copper wires. At the power-station several car wheels are placed in good moist earth, the number to be determined by the number of wheels placed between the tracks, and connected by wires of sufficient size to the negative brushes of the generators. This, in addition to the rails and bond wires, will give an earth return that will largely assist in the economical operation of any road, providing the roadbed is not constructed upon ledge rock. This form of construction has been used on several large roads and excellent results have been obtained, greatly reducing the coal consumption at the power-station.

DIMENSIONS OF CARS.

CARS FOR STREET RAILWAY SERVICE.

	Length.	Seating Cap.	W't of Car Body.	Wt. with 30 h. p. Tr'ck.
Closed Car	16 ft.	22	4,000—5,000 lbs.	11,000—12,000 lbs.
	28 ft.	40	6,980 lbs.	19,400 lbs.
Open Car (8 bench)	24 ft.	40	3,500—4,500 lbs.	10,500—11,500 lbs.
(10 bench)	30 ft.	50	6,400 lbs.	19,000 lbs.

CARS FOR FREIGHT AND PASSENGER SERVICE.

	NARROW GAUGE.		STANDARD GAUGE.	
	Weight.	Load.	Weight.	Load.
8 wheel Flat	6,500 - 8,500 lbs.	20,000—30,000 lbs.	16,000—20,000 lbs.	26,000—40,000 lbs.
8 wheel Box	10,000—12,000 lbs.	20,000—30,000 lbs.	18,000—24,000 lbs.	26,000—40,000 lbs.
4 wheel Coal and Ore	4,000—6,000 lbs.	10,000—12,000 lbs.	7,000—8,000 lbs.	16,000—20,000 lbs.
Passenger Car.	20,000—22,000 lbs.	45—50 pass.	30,000—40,000 lbs.	56—60 pass.

Weights. — Railway Generators.

CLASS.	GENERATOR Complete, Without Bed-Plate.		BED-PLATE.		ARMATURE.		FIELD SPOOLS.		SERIES COILS.		PULLEY.	
	Net Wt.	Ship. Wt.	Net Wt.	Ship. Wt.	Net Wt.	Ship. Wt.	Net Wt.	Ship. Wt.	Net Wt.	Ship. Wt.	Net Wt.	Ship. Wt.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
D^{40}	6,332	7,270	1,850	2,000	850	1,030	230	340	86	125	76	150
D^{50}	7,300	8,465	2,150	2,300	1,075	1,340	310	450	80	125	87	150
D^{62}	10,320	11,505	2,220	2,500	1,465	1,740	590	740			126	175
4-100-650	11,570	12,835	2,040	2,200	2,020	2,300	840	1,020			255	350
4-200-425	24,585				4,140		1,600				1,200	
4-300-400	42,724				6,920		1,800				2,420	
4-500-350												

WEIGHTS. — RAILWAY MOTORS.

MOTOR.	MOTOR COMPLETE, Without Axle Gear or Gear Cover.		ARMATURE AND PINION.		FIELD SPOOL.		AXLE GEAR.	
	Net Weight.	Shipping Weight.	Net Weight.	Shipping Weight.	Net Weight.	Shipping Weight.	Net Weight.	Shipping Weight.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
F. 20 A.	1,400	1,850	223	275	68	168	72	72
F. 30 A.	1,975	2,450	331	375 385	83	210	121	121
F. 40	2,715	3,350	419	480	158	360	133	133
G. 30	1,705	2,200	325	400	50	130	72	72
S. R. G. 30	2,060	3,150	484	585	128	310	215	215
W. P. 30	1,650	2,380	570	890	132	195	215	215
W. P. 50	2,230	3,050	815	1,075	153	250	215	215

Weights.—Motor Trucks.

MAKE OF TRUCK.	Weight of Wheel.	Diam. of Wheel.	Gauge.	Weight of Truck. (bare)	Weight of Truck Equipped with					
					S. R. G. 30.		W. P. 30.		W. P. 50.	
					One Motor.	Two Motors.	One Motor.	Two Motors.	One Motor.	Two Motors.
Bemis, 4 wheel,	250	30″	4′ 8½″	3,123	5,500	7,800	5,100	7,000	5,700	8,200
Brill, 4 wheel,	300	30″	4′ 8½″	3,500	5,800	8,100	5,400	7,300	6,000	8,500
McGuire, 4 wheel,	300	30″	4′ 8½″	3,000	5,300	7,600	4,900	6,800	5,500	8,000
Tripp, 4 wheel,	280	30″	4′ 8½″	3,600	5,900	8,200	5,500	7,400	6,100	8,600
Bemis, 8 wheel,	300	30″	4′ 8½″	3,120* each.	5,420	....	5,020	....	5,620	....
Brill, (Max. Tract.)	300 200	30″ 22″	4′ 8½″	2,700* each.	5,000	....	4,600	....	5,200	....
Tripp, 8 wheel,	280	30″	4′ 8½″	3,200* each.	5,500	....	5,100	....	5,700	....
Robinson Radial,	300 200	30″ 24″	4′ 8½″	5,000	7,300	9,600	6,900	8,800	7,500	10,000

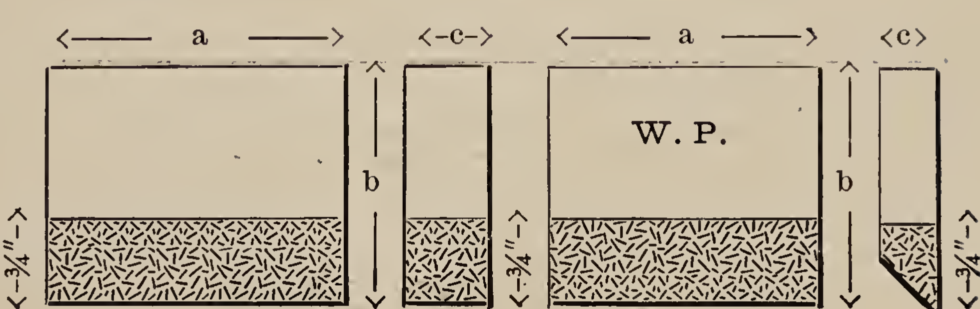
*There are two of these trucks per car, making the total weight of trucks per car twice the weight above given.

DIMENSIONS

OF

CARBON BRUSHES.

No. of Brush.	MACHINE.	*a*	*b*	*c*
4	F $^{20 \& 30}$ G ^{30} S R G $^{30 \& 50}$ Railway Motor.	2¼″	1¾″	½″
5	D ^{62} M. P. ^{90} Ry. Generator, and 4—100—650.	2¼″	2¼″	⅝″
6	F ^{40} Railway Motor.	2⅞″	2¼″	½″
8	4—300—400 and 4—500—350, Railway Generator.	2¼″	3½″	⅝″
11	W. P. ^{50} Ry. Motor, (Bevelled)	2⅞″	2½″	½″
12	W. P. ^{30} Ry. Motor, (Bevelled)	2¼″	2½″	½″



MISCELLANEOUS DATA

FOR

TRACK CONSTRUCTION.

RAILS.

$$\left.\begin{array}{r}\text{Tons (2240 lbs.) of Rail}\\ \text{per mile single track}\end{array}\right\} = \tfrac{11}{7} \times \left\{\begin{array}{l}\text{Weight of Rail in lbs.}\\ \text{per yard length.}\end{array}\right.$$

$$\text{Area of Rail (sq. in.)} = \frac{\text{Weight in lbs. per yard}}{10}$$

Usual length of Rail = 30 feet.

No. of rails per mile single track = 352.

TIES.

$$\left.\begin{array}{r}\text{Ordinary dimensions for}\\ 4', 8\tfrac{1}{2}'' \text{ Gauge.}\end{array}\right\} \; 7\tfrac{1}{2}' \times 9'' \times 7''$$

No. per mile:

3′	on centres	1760
2½′	,, ...	2112
2′	,, ...	2640

FISH PLATES.

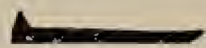
Usual length, 2 feet.

Weight per joint, 20 lbs.

4 bolts to each joint.

SPIKES.

A keg of Spikes weighs about 150 lbs.



Size in common use, $5\frac{1}{2}'' \times \frac{9}{16}'' \times \frac{9}{16}''$

No. per keg of 150 lbs............289

No. per pound......................1.93

No. of Spikes required for 1 mile of single track:

2,640 ties, 4 spikes per tie,	=	10,560
Rail guard at road crossing,	=	120
Turnouts, Sidings, loss, etc.,	=	700
Total, . . .		11,380 6,000 lbs. 40 kgs.

DIMENSIONS OF POLES.

Wooden Poles.	Length.	Diam. at Top.	Diam. at Bottom.		Weight of one Pole. Approx.	No. of Poles per Carload.
Cedar	28′	7″	9″		400	80
	30′	8″	10″		450	70
Georgia Pine (sawed square)	28′	7″	9″		600	50
	30′	8″	10″		850	35

Iron Poles.	Length.	Diam. Bottom Section.	Diam. Middle Section.	Diam. Top Section.	Weight of one Pole.	No. of Poles per Carload.
Standard Weight	30′	7″	6″	5″	lbs. 600	50
	28′	6″	5″	4″	485	62
	27′	5″	4″	3″	350	86
Extra Strong,	30′	7″	6″	5″	1,080	28
	28′	6″	5″	4″	750	40
	27′	5″	4″	3″	525	57

DIMENSIONS AND RESISTANCE

PURE COPPER WIRE.

Gauge	Dia.	AREA		Res. pure Cu, 75° F	Sp. gr. = 8.9 Weight		Length	Safe Carrying Capacity
American or B.S.G.	In. d	Sq. in. d²x.7854	Circ. mils. d²	Ohms per 1000′	Lbs. per 1000′	Lbs. per Mile.	Feet per Pound.	Amp. 80° F rise.
0000	.460	.1662	211600	.04906	639	3376	1.56	312
000	.409	.1318	167805	.06186	507	2677	1.97	262
000	.364	.1046	133079	.07801	402	2123	2.49	220
0	.324	.0824	104976	.09831	319	1685	3.13	185
1	.289	.0657	83694	.12404	253	1335	3.95	156
2	.257	.0521	66373	.15640	201	1059	4.99	131
3	.229	.0413	52634	.19723	159	840	6.29	110
4	.204	.0328	41742	.24869	126	666	7.93	92
5	.182	.0260	33102	.31361	100	528	10.00	78
6	.162	.0206	26250	.39546	79	419	12.61	65
7	.144	.0163	20736	.49871	63	332	15.90	55
8	.128	.0129	16384	.62881	50	263	20.05	46
9	.114	.0103	13094	.79281	40	209	25.28	39
10	.102	.0082	10481	1.0000	31	166	31.38	33
11	.090	.0065	8234	1.2607	25	137	40.20	27
12	.080	.0051	6400	1.5898	20	104	50.69	23
13	.072	.0041	5184	2.0047	16	83	63.91	19
14	.064	.0032	4095	2.5908	12	66	80.59	16
15	.057	.0026	3256	3.1150	10	52	101.63	14
16	.051	.0020	2581	4.0191	8	41	128.14	11
17	.045	.0016	2048	5.0683	6	33	161.59	10
18	.040	.0013	1660	6.3911	5	26	203.76	8
19	.036	.0010	1296	8.2889	4	20	264.26	7
20	.032	.0008	1024	10.163	3	16	324.00	6

$\left((M) = c^{\frac{4}{3}} \times 100 \right)$

Resistance of 1 mile pure copper wire 1-16 inch in diameter equals 13.59 ohms at 15.5° C, or 59.9° F.

WEIGHTS OF

Iron, Steel, and Silicon Br. Wire.

AMERICAN GAUGE.

No. of Gauge.	Size of each No. In.	WEIGHT OF WIRE Per 1000 Lineal Feet.		
		Wrought Iron.	Steel.	Silicon Bronze.
				APPROXIMATE.
0000	.460	561.	566.	639
000	.409	445.	449.	507
00	.364	353.	356.	402
0	.324	280.	282.	319
1	.289	222.	224.	252
2	.257	176.	178.	200
3	.229	139.	141.	159
4	.204	111.	112.	126
5	.182	87.7	88.5	100
6	.162	69.6	70.2	79
7	.144	55.2	55.7	62
8	.128	43.8	44.1	50
9	.114	34.7	35.0	40
10	.102	27.5	27.8	31
11	.090	21.8	22.0	25
12	.080	17.3	17.5	20
13	.072	13.7	13.9	15
14	.064	10.9	11.0	12
15	.057	8.63	8.71	10
16	.051	6.85	6.91	8
17	.045	5.43	5.48	6
18	.040	4.30	4.34	5
19	.036	3.41	3.45	4
20	.032	2.71	2.73	3
Specific Grav...........		7.77	7.85	8.88
W't per Cubic Ft.......		486.	490.	555.

Approximate Weights of Several Brands of Insulated Wire.

	AM. CIRC. LOOM CO.	K. K. INS. WIRE.	SIMPLEX.	CANDEE.		AMERICAN ELEC. WORKS.
Gauge No.	Double Braid.	Triple Braid.	T. Z. R.	Weatherproof. Stranded.	Weatherproof. Solid.	Weatherproof. 3 Braided.
B. & S.	Wt. per mile.	Wt. per mile.	Wt. per mile.	Wt. per mile.	Wt. per mile.	Wt. per mile.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
0000	4,023	3,727	3,940	4,470	....	3,920
000	3,255	3,168	3,200	3,250	....	3,215
00	2,640	2,640	2,520	2,920	2,638	2,575
0	2,160	2,112	2,040	2,160	2,120	2,060
1	1,745	1,473	1,640	1,760	1,726	1,625
2	1,426	1,267	1,255	1,440	1,339	1,260
3	1,168	1,093	1,015	1,227	1,095	1,030
4	961	834	810	1,042	900	860
5	792	681	665	844	739	710
6	....	....	....	....	....	585

NOTE. — The above weights were taken from the catalogues of the companies manufacturing the several brands of Insulated Wire.

COMPARATIVE TABLE

OF

WIRE GAUGES.

American Gauge.		Birmingham Gauge.		British Standard Gauge.	
No. A. W. G.	Diameter in inches.	No. B.W.G.	Diameter in inches.	No. S.W.G.	Diameter in inches.
0000	.4600	0000	.454	0000	.400
000	.4096	000	.425	000	.372
00	.3648	00	380	00	.348
0	.3249	0	.340	0	.324
1	.2896	1	.300	1	.300
2	.2576	2	.284	2	.276
3	.2294	3	.259	3	.252
4	.2043	4	.238	4	.232
5	.1819	5	.220	5	.212
6	.1620	6	.203	6	.192
7	.1443	7	.180	7	.176
8	.1285	8	.165	8	.160
9	.1144	9	.148	9	.144
10	.1019	10	.134	10	.128
11	.0907	11	.120	11	.116
12	.0808	12	.109	12	.104
13	.0720	13	.095	13	.092
14	.0641	14	.083	14	.080
15	.0571	15	.072	15	.072
16	.0508	16	.065	16	.064
17	.0453	17	.058	17	.056
18	.0403	18	.049	18	.048
19	.0359	19	.042	19	.040
20	.0320	20	.035	20	.036

Equivalent Cross Sections of Wires.

B. & S. GAUGE.

0000	2– 0	4– 3	8– 6	16– 9	32–12	64–15	128–18
000	2– 1	4– 4	8– 7	16–10	32–13	64–16	....
00	2– 2	4– 5	8– 8	16–11	32–14	64–17	1 and 3
0	2– 3	4– 6	8– 9	16–12	32–15	64–18	2 ,, 4
1	2– 4	4– 7	8–10	16–13	32–16	....	3 ,, 5
2	2– 5	4– 8	8–11	16–14	32–17	....	4 ,, 6
3	2– 6	4– 9	8–12	16–15	32–18	....	5 ,, 7
4	2– 7	4–10	8–13	16–16	....	....	6 ,, 8
5	2– 8	4–11	8–14	16–17	....	....	7 ,, 9
6	2– 9	4–12	8–15	16–18	....	....	8 ,, 10
7	2–10	4–13	8–16	....	....	....	9 ,, 11
8	2–11	4–14	8–17	....	....	....	10 ,, 12
9	2–12	4–15	8–18	....	....	....	11 ,, 13
10	2–13	4–16	....	....	....	....	12 ,, 14
11	2–14	4–17	....	....	....	....	13 ,, 15
12	2–15	4–18	....	....	....	....	14 ,, 16
13	2–16	....	....	....	....	....	15 ,, 17
14	2–17	....	....	....	....	....	16 ,, 18
15	2–18	....	....	....	....	....	....

American
Screw Gauge.

No.	Diameter in inches.	No.	Diameter in inches.
0	.0578	13	.2289
1	.0710	14	.2421
2	.0842	15	.2552
3	.0973	16	.2684
4	.1105	17	.2816
5	.1236	18	.2947
6	.1368	20	.3210
7	.1500	22	.3474
8	.1631	24	.3737
9	.1763	26	.4000
10	.1894	28	.4263
11	.2026	30	.4520
12	.2158		

FEET EXPRESSED IN DECIMAL PARTS OF A MILE.

	UNITS.	10s	100s	1000s
1	.000189	.001893	.01893	.1893
2	.000378	.003787	.03787	.3787
3	.000568	.005681	.05681	.5681
4	.000757	.007574	.07574	.7574
5	.000946	.009468	.09468	.9468
6	.001136	.011362	.11362	
7	.001325	.013255	.13255	
8	.001514	.015148	.15148	
9	.001704	.017042	.17042	

TABLE OF DECIMAL EQUIVALENTS

OF

8ths, 16ths, 32ds, and 64ths of an inch.

8THS.	$\frac{9}{32} = .28125$	$\frac{19}{64} = .296875$
$\frac{1}{8} = .125$	$\frac{11}{32} = .34375$	$\frac{21}{64} = .328125$
$\frac{1}{4} = .250$	$\frac{13}{32} = .40625$	$\frac{23}{64} = .359375$
$\frac{3}{8} = .375$	$\frac{15}{32} = .46875$	$\frac{25}{64} = .390625$
$\frac{1}{2} = .500$	$\frac{17}{32} = .53125$	$\frac{27}{64} = .421875$
$\frac{5}{8} = .625$	$\frac{19}{32} = .59375$	$\frac{29}{64} = .453125$
$\frac{3}{4} = .750$	$\frac{21}{32} = .65625$	$\frac{31}{64} = .484375$
$\frac{7}{8} = .875$	$\frac{23}{32} = .71875$	$\frac{33}{64} = .515625$
	$\frac{25}{32} = .78125$	$\frac{35}{64} = .546875$
16THS.	$\frac{27}{32} = .84375$	$\frac{37}{64} = .578125$
$\frac{1}{16} = .0625$	$\frac{29}{32} = .90625$	$\frac{39}{64} = .609375$
$\frac{3}{16} = .1875$	$\frac{31}{32} = .96875$	$\frac{41}{64} = .640625$
$\frac{5}{16} = .3125$		$\frac{43}{64} = .671875$
$\frac{7}{16} = .4375$	**64THS.**	$\frac{45}{64} = .703125$
$\frac{9}{16} = .5625$	$\frac{1}{64} = .015625$	$\frac{47}{64} = .734375$
$\frac{11}{16} = .6875$	$\frac{3}{64} = .046875$	$\frac{49}{64} = .765625$
$\frac{13}{16} = .8125$	$\frac{5}{64} = .078125$	$\frac{51}{64} = .796875$
$\frac{15}{16} = .9375$	$\frac{7}{64} = .109375$	$\frac{53}{64} = .828125$
32DS.	$\frac{9}{64} = .140625$	$\frac{55}{64} = .859375$
$\frac{1}{32} = .03125$	$\frac{11}{64} = .171875$	$\frac{57}{64} = .890625$
$\frac{3}{32} = .09375$	$\frac{13}{64} = .203125$	$\frac{59}{64} = .921875$
$\frac{5}{32} = .15625$	$\frac{15}{64} = .234375$	$\frac{61}{64} = .953125$
$\frac{7}{32} = .21875$	$\frac{17}{64} = .265625$	$\frac{63}{64} = .984375$

List of Printed Matter Relative to Electric Railways issued by the Bureau of Information, General Electric Company, Boston, Mass.

Railway Bulletins of Information.

Snow-sweepers	No. 1001
Overhead Parts	,, 1002
Railway Power Generators	,, 1003
W. P. Railway Motors	,, 1004

Papers.

Additional Burdens on Street Railways, by H. M. Whitney.

Article on T.-H. Factory, Lynn, Mass. Electrical Engineer, June 29, 1892.

Electric Railways, by Eugene Griffin, in Journal of Franklin Institute, April, 1890.

West End Power-station, Boston, Mass, Electrical Engineer, October 21, 1891.

The Utilization of Electric Power at the Schenectady Works, Electrical Engineer, Feb. 3, 1892.

Legal Reports.

Testimony introduced by T.-H. E. Co., in support of their contract with Eckington and Soldiers' Home Railway Co., Washington, D. C., 1888.

An injunction denied by Judge Zane. Bell Telephone Co. v. Salt Lake City Electric Railway Co., 1889.

Rights of Electric Street Railways, Supreme Court of Rhode Island, January, 1889.

Detroit City Railway Co. v. Merrill B. Mills, Circuit Court, Wayne County, Mich., 1889.

F. W. Pelton v. East Cleveland Railroad Co., Court of Common Pleas, Cuyahoga County, Ohio, 1889.

Superior Court of Cincinnati — Cincinnati Inclined Plane Railway Co. v. City and Suburban Telephone Co., 1890.

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Extracts from U. S. Senate Report on the Safety of Overhead Wires, August, 1888.

Manual of Expenses on Electric Street Railways.

Safety of Overhead Wires. Letters from Mayors of Cities.

Results of the Use of Electricity for Street Railways. Reprint from Boston "Advertiser."

List of Periodicals to which Electric Street Railway Men Should Subscribe.

Electrical Engineer	(Weekly)	New York
Electrical Industries	(Monthly)	Chicago, Ill.
Electric Power	,,	New York
Electrical Review	(Weekly)	,,
Electrical World	,,	,,
Engineering Magazine	(Monthly)	,,
Journal of Franklin Institute	,,	Philadelphia
Railroad and Engineering Journal	,,	New York
Railroad Gazette	,,	,,
Street Railway Gazette	(Weekly)	Chicago, Ill.
Street Railway Journal	(Monthly)	New York
Street Railway Review	,,	Chicago, Ill.
Western Electrician	(Weekly)	,,